Non-invasive (in-memory) instrumentation

Toshihito Kikuchi

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Agenda

- Background
- What can be done
- How it works
- How to use
- Demo 1: Bottleneck analysis of Chrome function
- Demo 2: Comparative analysis between BlinkGC and MemGC

- The latest slides are available in https://github.com/msmania/procjack/blob/master/clove/Intro.pdf

Background

- Many situations where you want to instrument a code
  - To exercise an unusual codepath
  - To measure the performance of some operations
  - To reproduce a race condition
  - To collect more logs to understand the behavior
  - etc.
- Instrumentation is not always easy
  - Time consuming
    (e.g. Chromium takes hours to build unless you're a Googler or rich..)
  - Impossible if you don't have code or build environment
    (e.g. Customer's code, 3rd-party, malware)
  - Compiler optimization varies
    (e.g. PGO build)

What can be done

- Non-invasive instrumentation enables you to
  - Inject your code in arbitrary places
    (including the middle of a function)
  - Without modifying the target program

- Leveraging two techniques
  - Reflective DLL Injection: to inject DLL into a running process
  - Microsoft Detours: to hook the existing code

- Some limitations
  - Some spots cannot be hooked due to the nature of Detours
  - Not available for IA64/ARM/Linux/Kernel-Mode

How it works: Reflective DLL Injection

- Famous way to inject your code into a running process
  - Leveraging VirtualAllocEx and CreateRemoteThread, you can invoke your DLL's DLLMain in a target process
  - Included in Metasploit

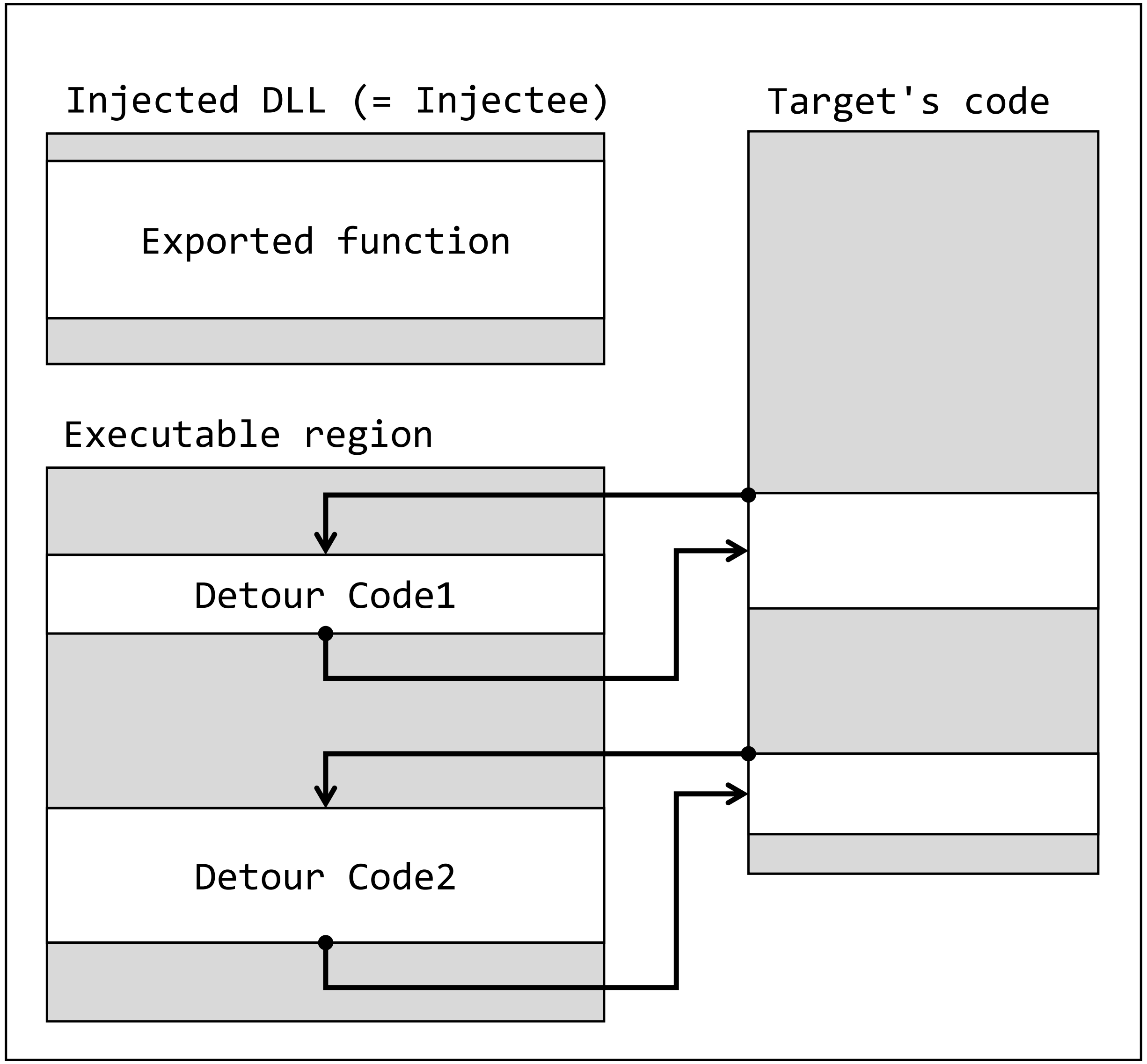
- Advanced version in ProcJack
  - You can invoke a DLL-exported function instead of DLLMain
  - You can invoke a DLL-exported function with a string parameter that is passed into the function.

How it works: Microsoft Detours

- MSR's weapon to hook the code
    - Dynamically modifies the code to hook in an elegant way
        - 1. Disassembly the original code
        - 2. Move the original code to a different place as a trampoline function
        - 3. Put *jmp +rel32* on the hooking position
- Version 3.0 was available for a long time
    - Free version (Detours Express) supported only x86
    - Detours Professional supported x64, but it was $9,999.95
- Version 4.0.1 is now available
    - Open-sourced on GitHub
    - MIT License
    - Supports x86/x64/IA64/ARM/ARM64

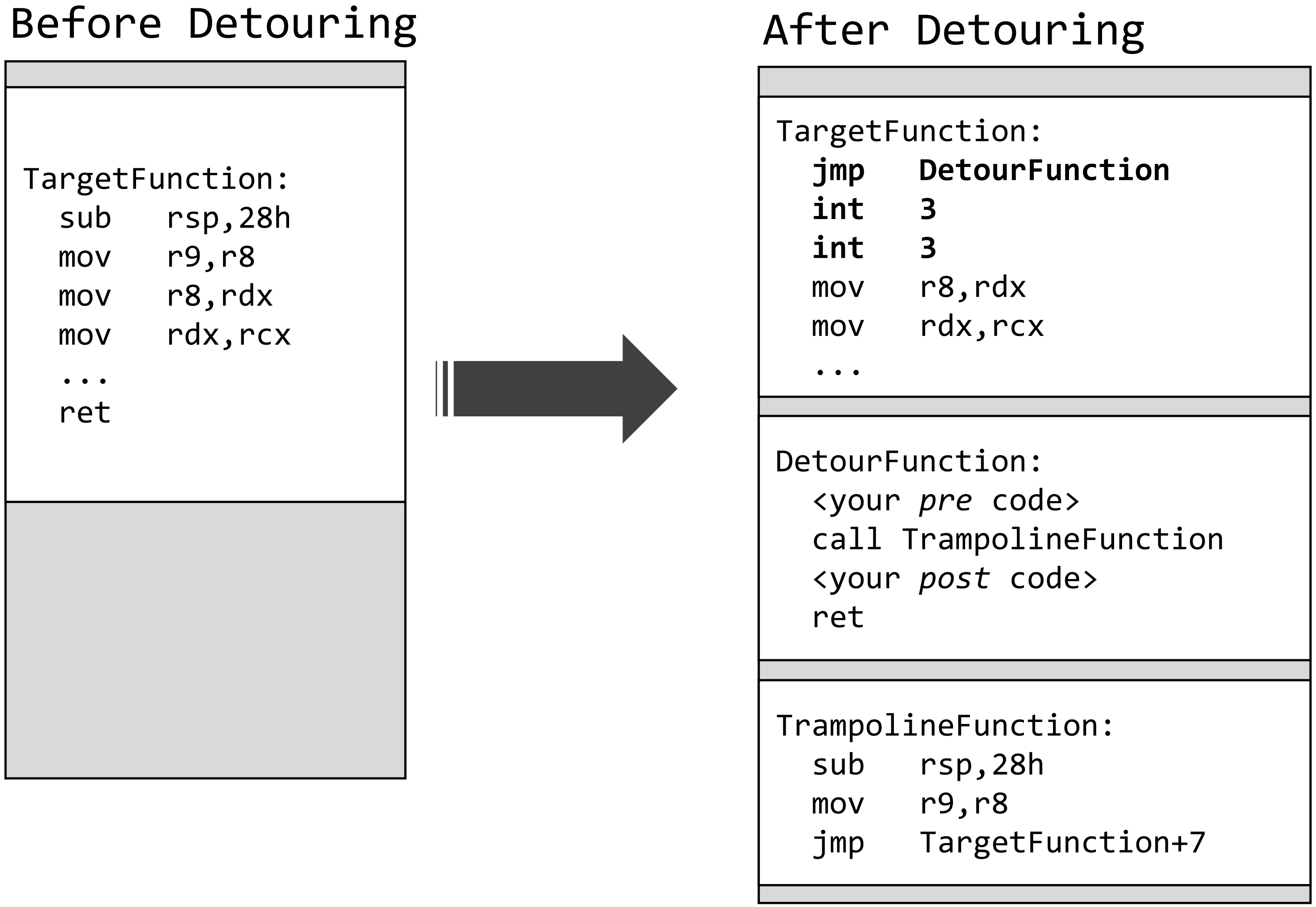
How it works: DLL injection meets Detours

1. Inject a DLL into the process
2. Run a DLL function in a new thread
3. Allocate an executable region
4. Plant detour codes in the region
5. Detour the target's codes into the detour codes



How it works: Detouring details

- Detours basically detours a function's start address



Before Detouring

```
TargetFunction:
  sub   rsp,28h
  mov   r9,r8
  mov   r8,rdx
  mov   rdx,rcx
  ...
  ret
```

After Detouring

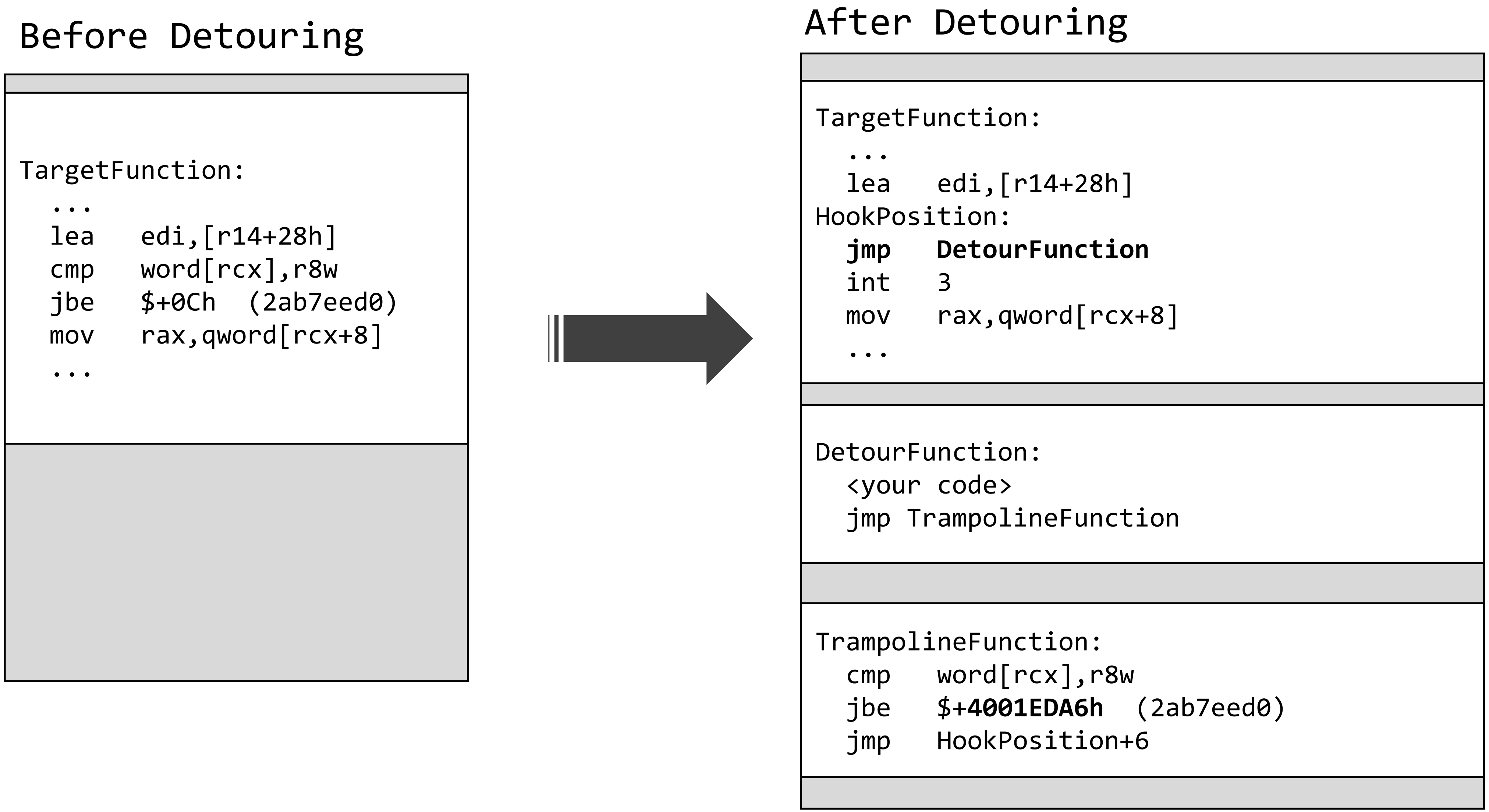
```
TargetFunction:
  jmp   DetourFunction
  int   3
  int   3
  mov   r8,rdx
  mov   rdx,rcx
  ...
```

```
DetourFunction:
  <your pre code>
  call TrampolineFunction
  <your post code>
  ret
```

```
TrampolineFunction:
  sub   rsp,28h
  mov   r9,r8
  jmp   TargetFunction+7
```

How it works: Detouring details

- A way to hook a code in the middle of a function



Before Detouring

```
TargetFunction:
  ...
  lea   edi,[r14+28h]
  cmp   word[rcx],r8w
  jbe   $+0Ch  (2ab7eed0)
  mov   rax,qword[rcx+8]
  ...
```

After Detouring

```
TargetFunction:
  ...
  lea   edi,[r14+28h]
HookPosition:
  jmp   DetourFunction
  int   3
  mov   rax,qword[rcx+8]
  ...
```

```
DetourFunction:
  <your code>
  jmp TrampolineFunction
```

```
TrampolineFunction:
  cmp   word[rcx],r8w
  jbe   $+4001EDA6h  (2ab7eed0)
  jmp   HookPosition+6
```

How to use

- Command to inject/run DLL:

```
> pj.exe [-d] [-w] <PID> <FILE>[?ORDINAL] [ARGS]
```

- Clove.dll is an injectee DLL to run Detours
  - Ordinal#1 to show ProcessMitigation status
  - Ordinal#2 to release all hooks
  - Ordinal#3 to print results on the debugger console

  - Ordinal#100 (Explained in Demo1)
    ```
    > pj.exe <PID> clove.dll?100 <Addr1>-<Addr2>-…-<AddrN>
    ```
    to measure CPU cycles of each range [AddrX - AddrX+1]

  - Ordinal#200 (Explained in Demo2)
    ```
    > pj.exe <PID> clove.dll?200 <AddrX>
    ```
    to capture a context (registers and TID) at AddrX

Demo1

- Mission: Find a bottleneck of Chrome's layout code
  More specifically, where is the slowest operation in chrome_child!blink::Document::UpdateStyleAndLayoutTree?

- Plan:
  - 1. Define some ranges in the target function
  - 2. Measure CPU cycles of each range

- This demonstrates:
  - Hook the code in the middle of a function
  - Multiple injected codes interact with each other

Demo2

- Mission:
  Find the heap allocation pattern of BlinkGC and MemGC

- Plan:
  - Trace function calls of the following functions:
    - chrome_child!blink::Node::AllocateObject
    - edgehtml!MemoryProtection::HeapAllocClear<1>
  - Collect the following information
    - Caller's TID
    - Size to allocate

- This demonstrates:
  - Invoke a C++ function from the hook

References

- GitHub repo
  https://github.com/msmania/procjack/
- Microsoft Detours
  https://www.microsoft.com/en-us/research/project/detours/
  https://github.com/microsoft/detours