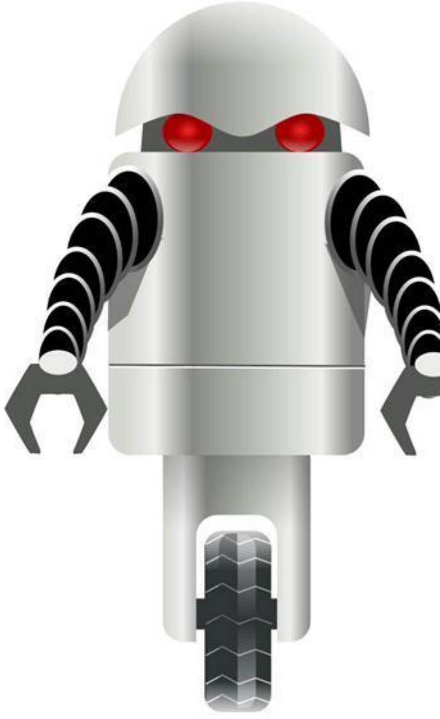
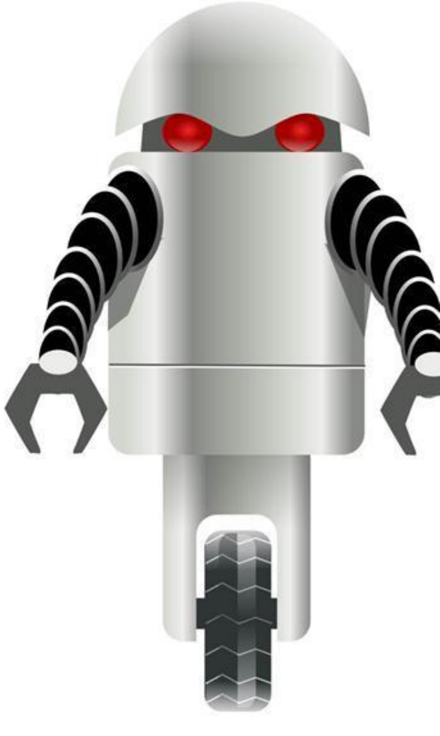
Why Don’t You Just Tell Me Where The ROP Isn’t Supposed To Go

David Dorsey
@trogdorsey



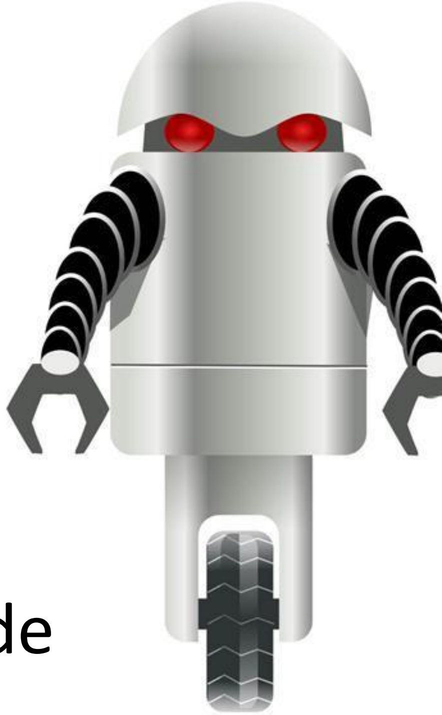
Who’s this… guy

- 10 years on the defensive side
- File analysis & RE
- Recently doing research using machine learning



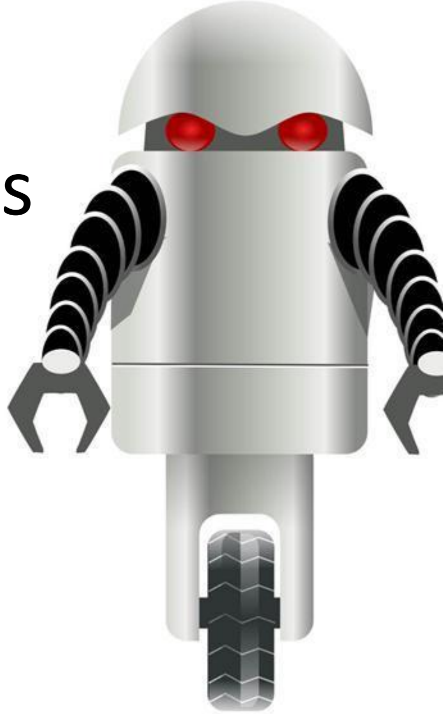
Level Setting

- ROP
  - Technique to bypass non-executable memory
  - Bounce around in memory executing small gadgets that typically end with a return instruction
- PIN
  - Pin is a dynamic binary instrumentation framework from Intel
  - Does not require recompiling of source code and can support instrumenting programs that dynamically generate code



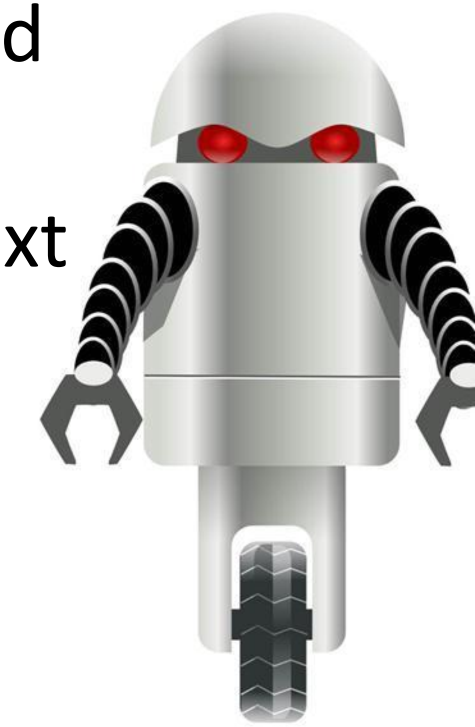
Basic Idea

- Control flow integrity
  - Start with coarse grain controls
- We know valid targets for calls and rets
  - Functions
  - Instructions after a call instruction
- A whitelist containing these addresses
- Store the offset to these locations
- If an indirect call or a ret goes to a different location, then ROP



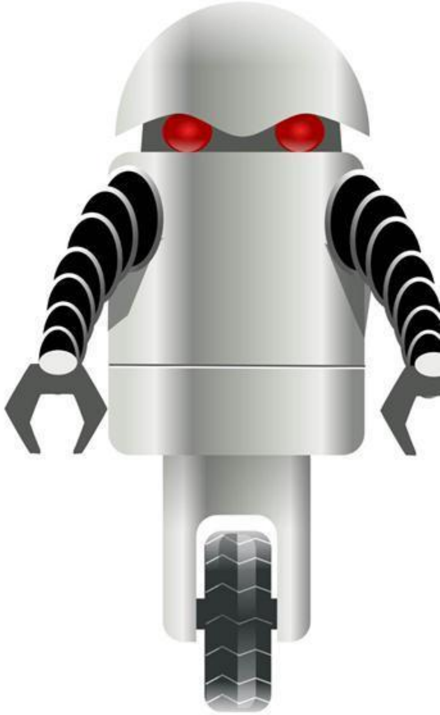
How Do We Get Those?

- BranchTargetDetector pintool
- When DLL is loaded, the exported functions are analyzed
- All calls and returns are instrumented as well
- Offsets are stored and dumped to text file when program exits



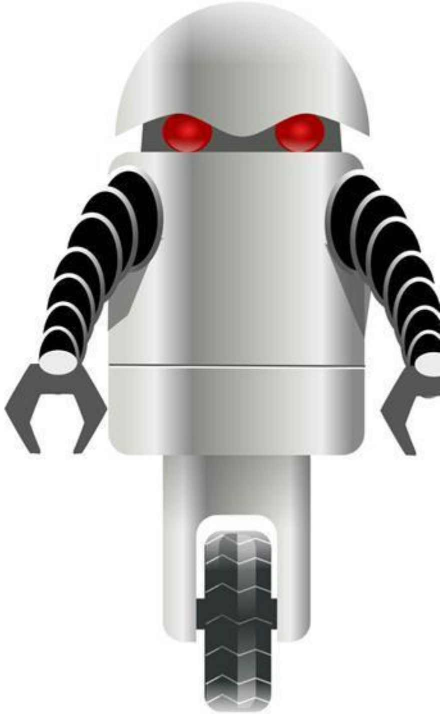
BranchTargetDetector

- Pros
  - We get real, actual used values
- Cons
  - Not the fastest thing
  - Only get values from functions pin can detect and what it actually executes
  - If DLL isn't loaded, you don't get data for it
  - Must run multiple times



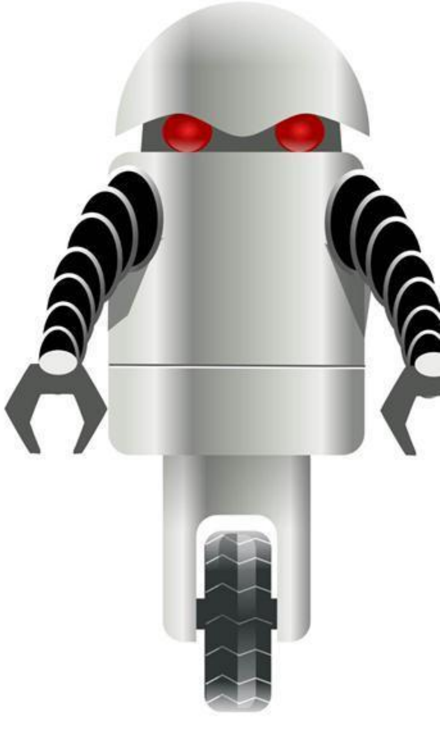
How Else Can We Get Those?

- pyew
- Much better at detecting functions
- Can extract the flow graphs
- Can bulk run all DLLs



Have Data, Now What?

- Store offsets in file per md5 hash of dll
- Allows for handling of different versions of the same dll

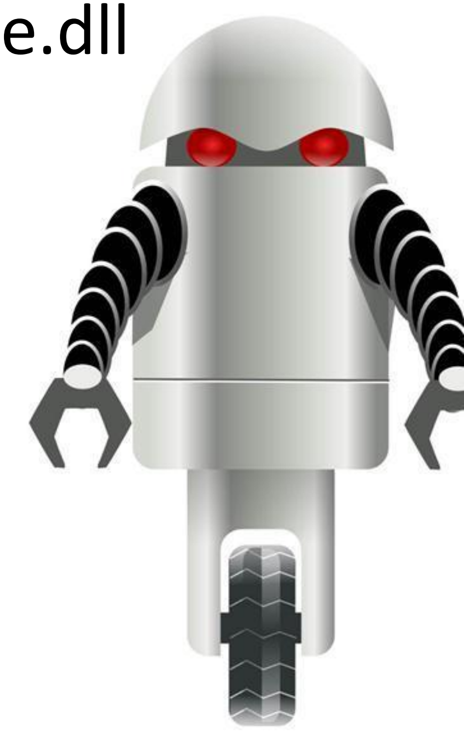


ROPDetector

- When a DLL is loaded, load the white list for that DLL
- Instrument all indirect calls and RETs and alert when target is not on the white list

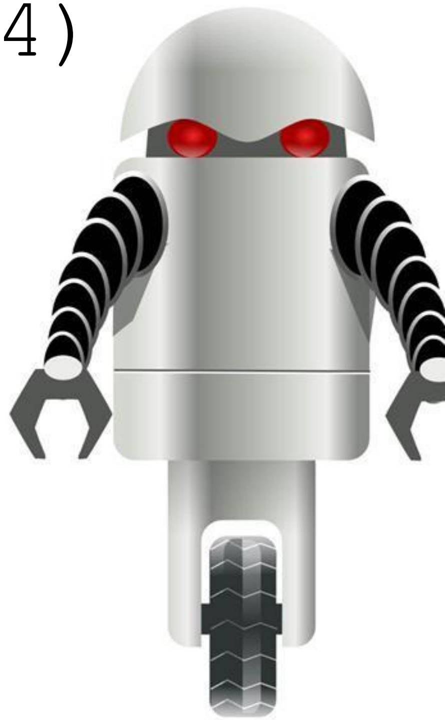
Example 1

- Adobe Reader 9.3 on Windows XP
- 32dbd816b0b08878bd332eee299bbec4
- CVE-2010-2883
    - Stack-based buffer overflow in CoolType.dll



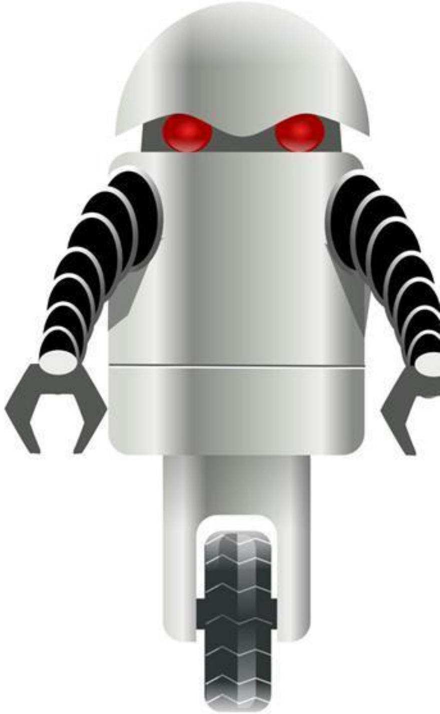
Detection!

```
C:\Program Files\Adobe\Reader
9.0\Reader\icucnv36.dll
0x4a80cb3f: ret
Target: 0x4a82a714 (0x2a714)
```

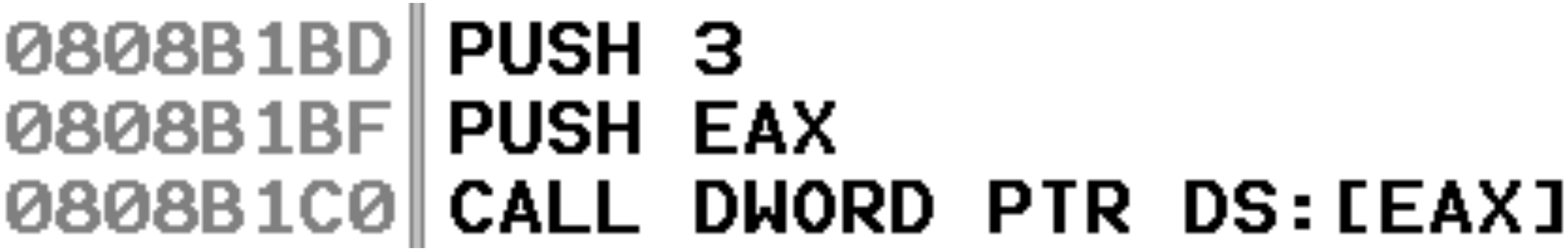


Yay?

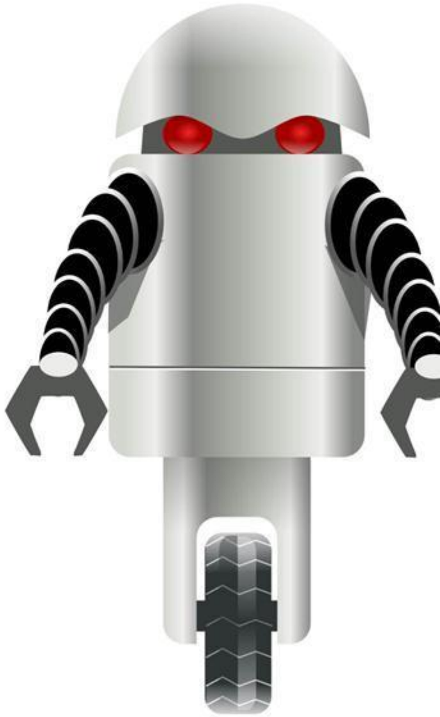
- We detected one of the ROP chains
- Only 1



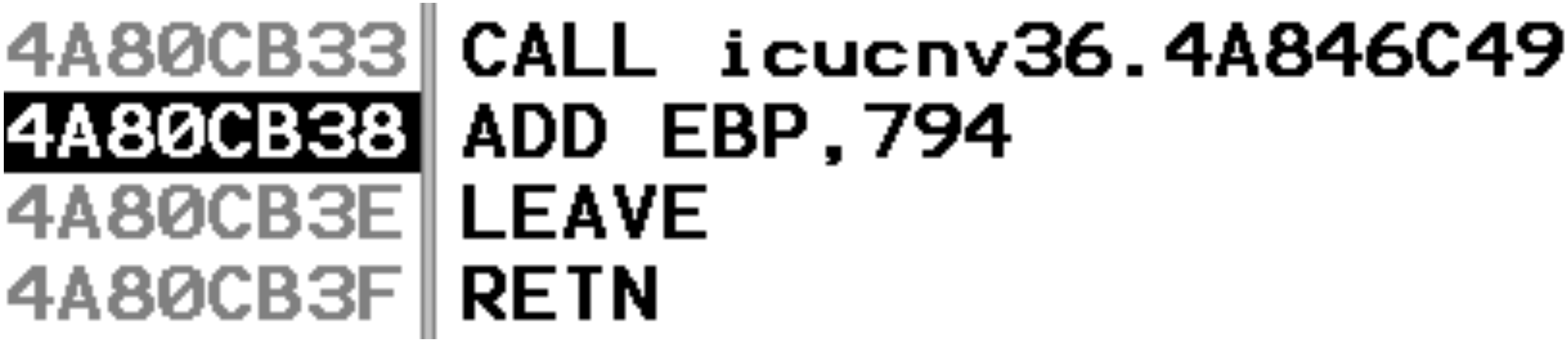
Let’s Take A Look



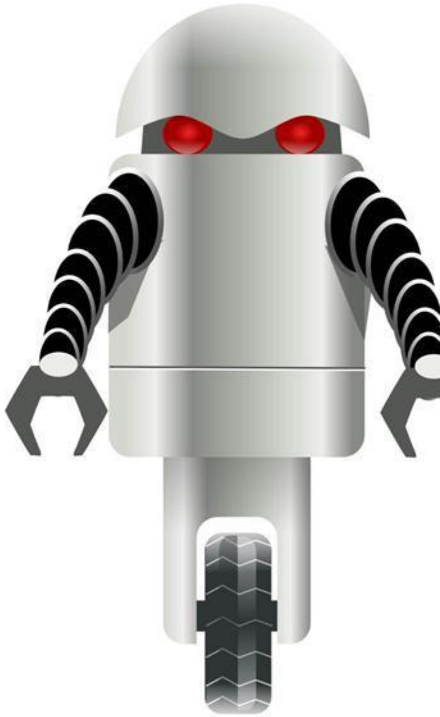
```
0808B1BD  PUSH 3
0808B1BF  PUSH EAX
0808B1C0  CALL DWORD PTR DS:[EAX]
```



Let’s Take A Look



```
4A80CB33  CALL icucnv36.4A846C49
4A80CB38  ADD EBP,794
4A80CB3E  LEAVE
4A80CB3F  RETN
```



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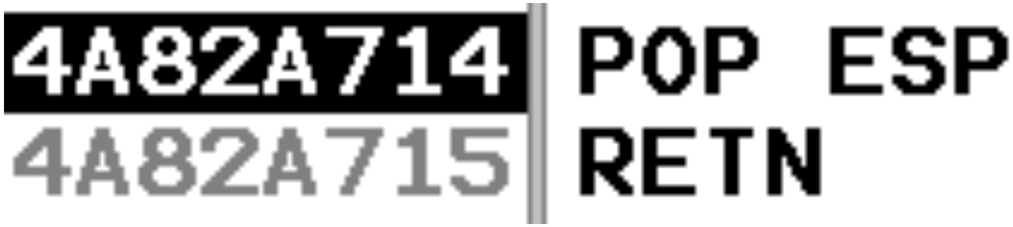
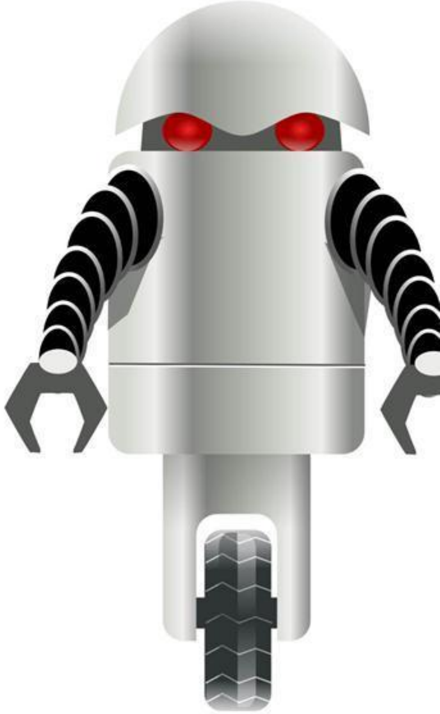


```
4A82A714  POP ESP
4A82A715  RETN
```



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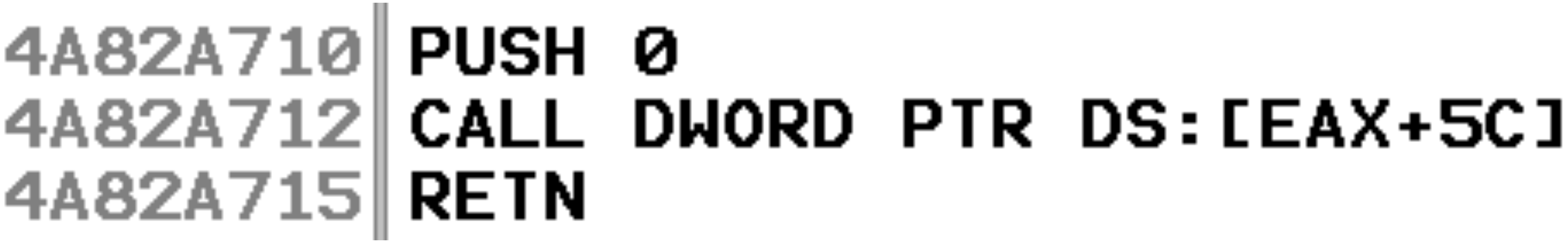
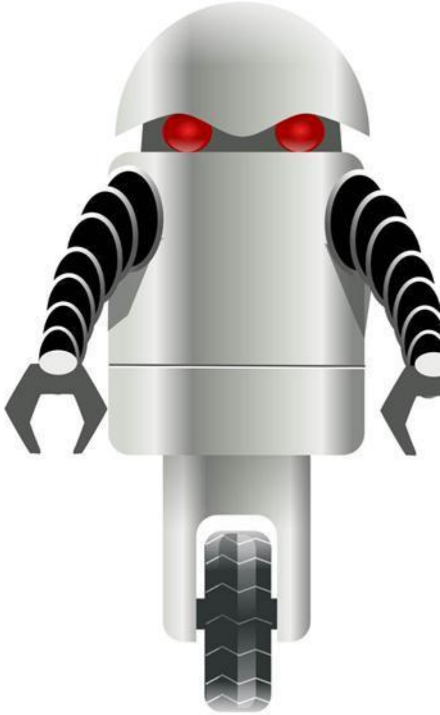
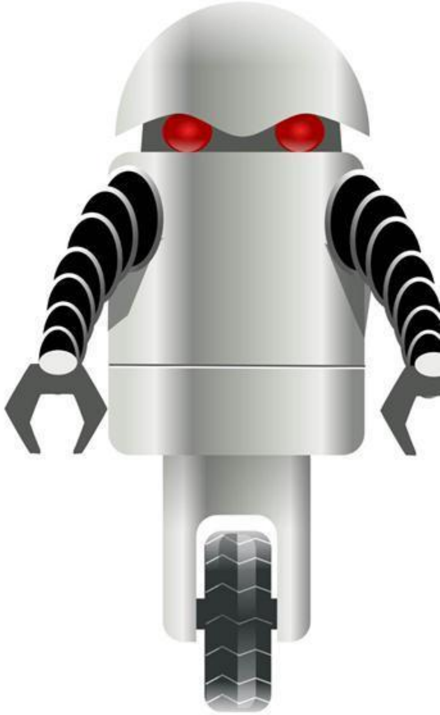


```
4A82A710  PUSH 0
4A82A712  CALL DWORD PTR DS:[EAX+5C]
4A82A715  RETN
```



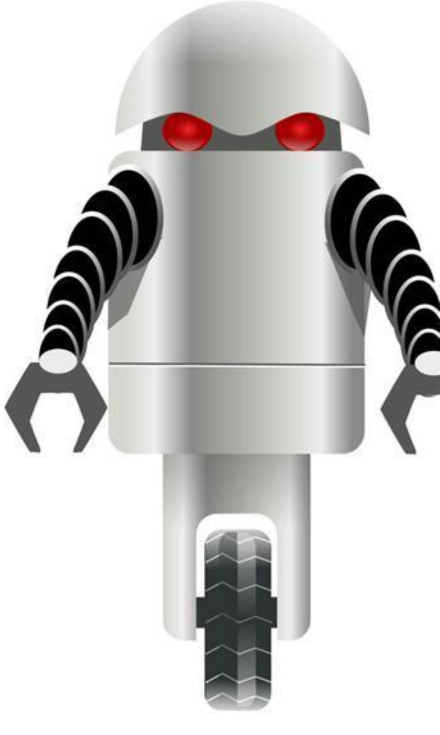
Why Only One?

- Dies on stack pivot
- Pin affects memory layout
  - Run everything in pin?



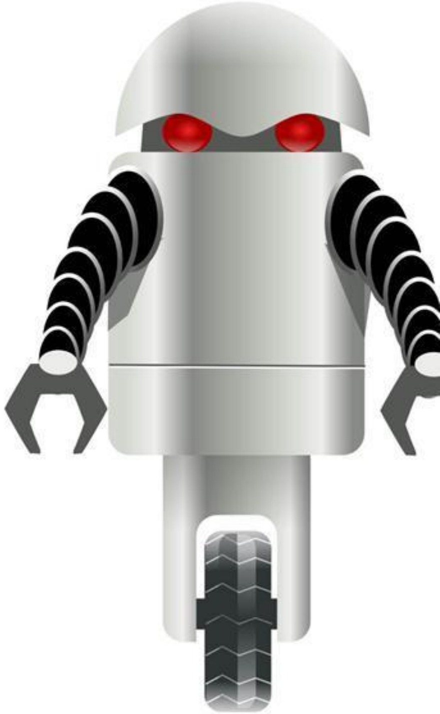
How Would We Have Done?

- 45 chains in ROP sequence
- Only 14 unique addresses
- 2 indirect calls, 43 returns
- 3 of the 14 addresses on whitelist
    - Each address only called once
- 42 of 45 chains would be detected



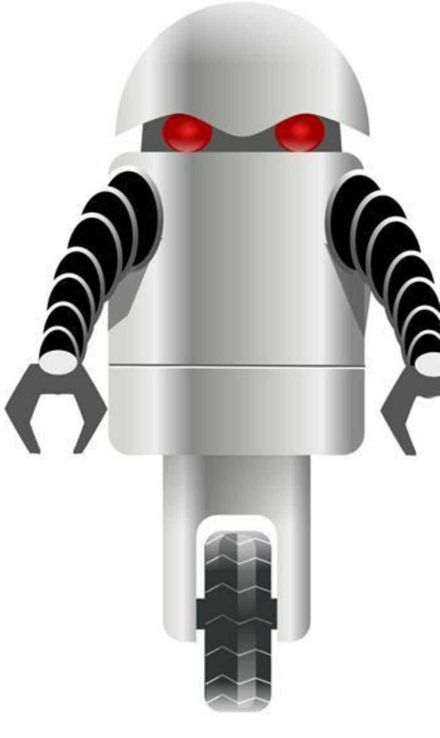
Example 2

- Adobe Reader 9.5 on Windows XP
- 6776bda19a3a8ed4c2870c34279dbaa9
- CVE-2013-3346
    - ToolButton Use After Free



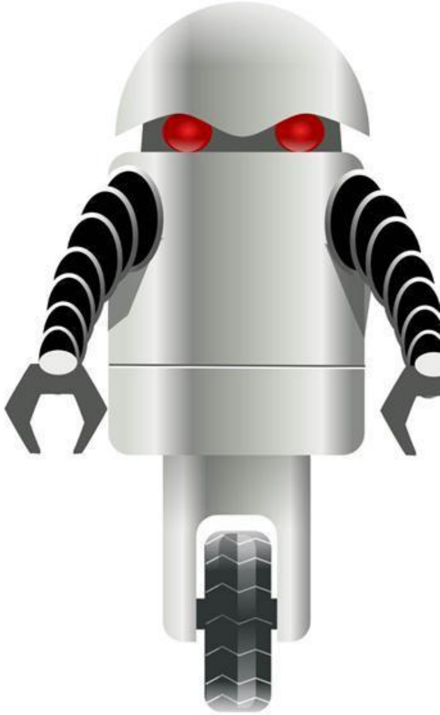
Example 2 Results

- Nothing, just Adobe crashing
- Pin affected up memory layout again



The Neighborhood Of Make Believe

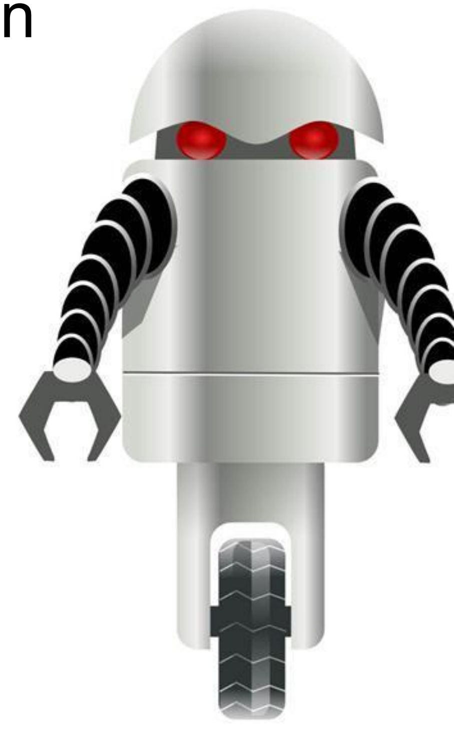
- 208 chains in ROP sequence
  - Dominated by 191 chain sled
- Only 15 unique addresses
- All returns
- 3 of the 15 addresses on whitelist
- 204 of 208 chains would be detected



A Little Math

- Probability of detecting at least one address (assuming 11/14 detections is average)

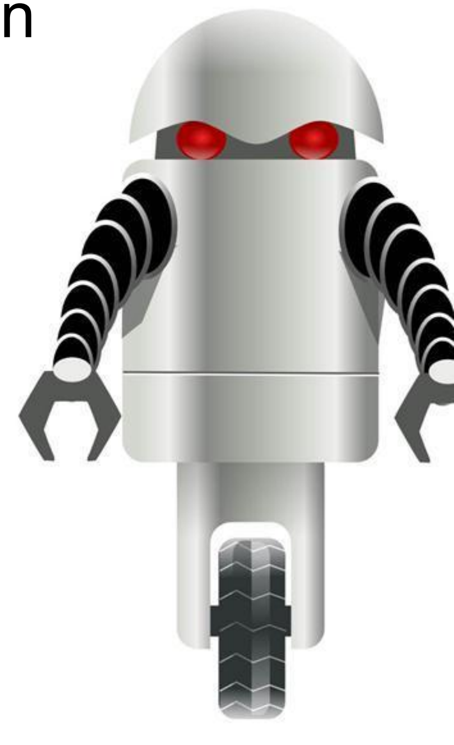
Unique Addresses	Probability of Detection
1	78.6%
2	95.4%
3	99.0%
4	99.8%
5	99.96%
10	99.999980%



A Little More Math

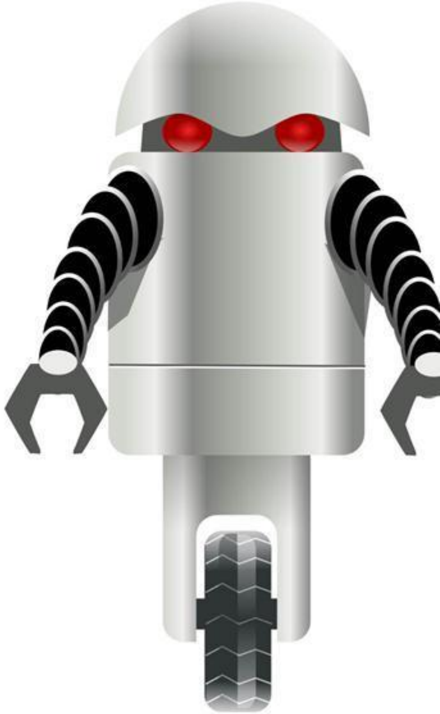
- Probability of detecting at least one address (assuming 50% detection rate)

Unique Addresses	Probability of Detection
1	50.0%
2	75.0%
3	87.5%
4	93.8%
5	96.9%
10	99.9%



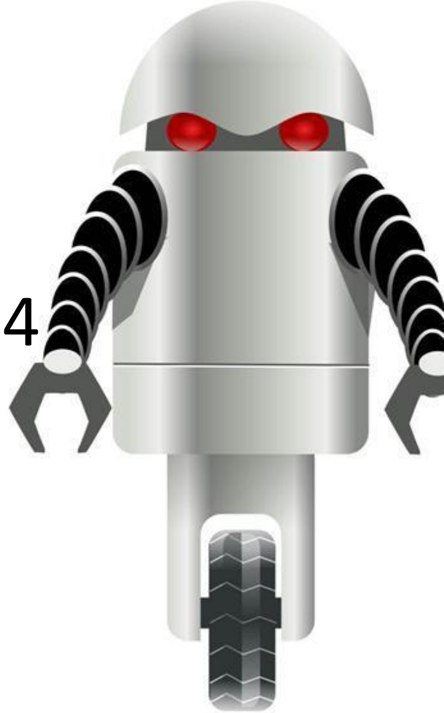
Limitations

- Pin
  - Breaks on stack pivot
  - Slow
- Doesn't handle Jump Oriented Programming (JOP)
- Only course grained control flow integrity



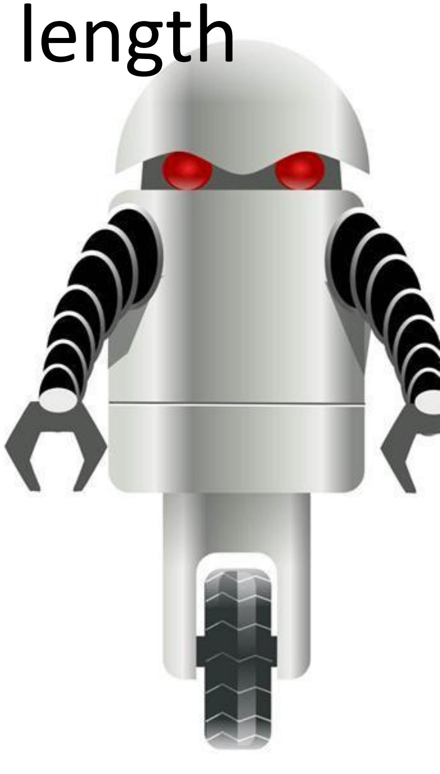
To Do List

- Figure out heap problem
- Smarter instrumentation
- Push analysis into a different thread
- Check for JOP
- Implement on OS X and Linux
- Implement fine grained controls
  - "The Beast Is In Your Memory" - BH 2014

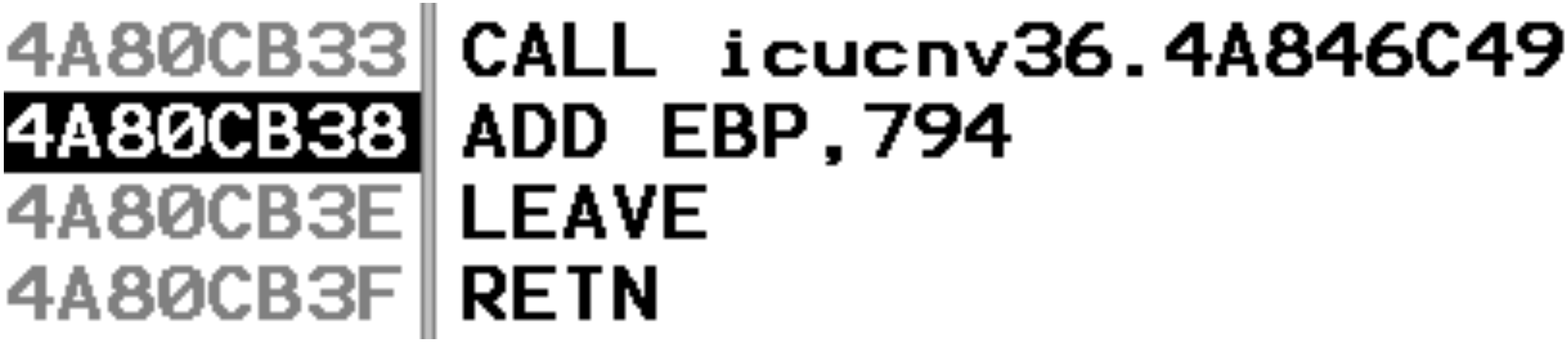


The Beast

- Defeated coarse grained CFI
  - EMET
  - This current implementation
- Defeated return frequency/sequence length heuristics
  - Kbouncer
  - ROPecker

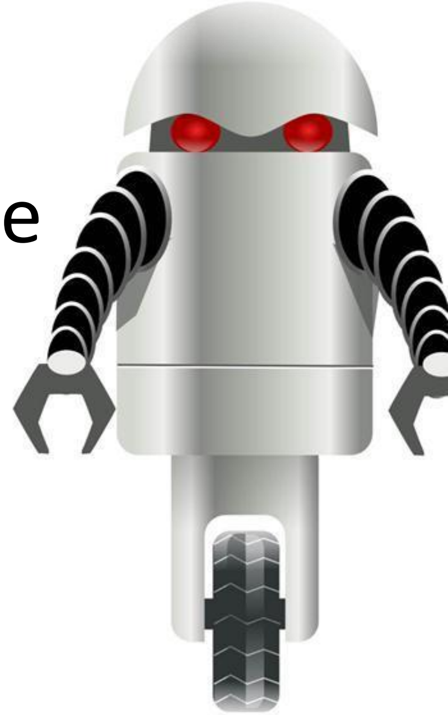


Fine Grained CFI



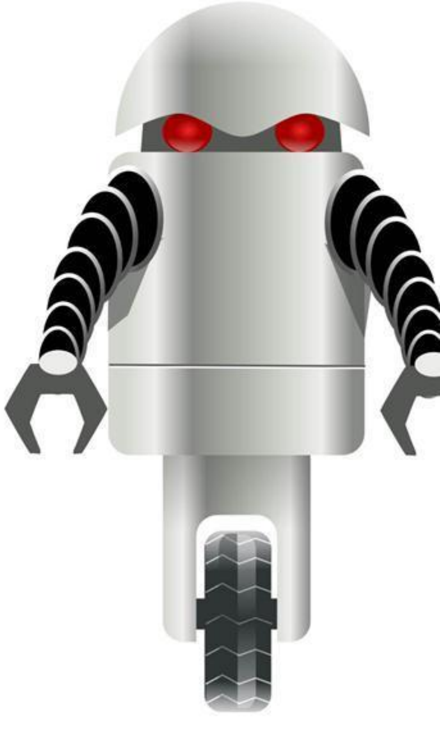
```
4A80CB33 CALL icucnv36.4A846C49
4A80CB38 ADD EBP,794
4A80CB3E LEAVE
4A80CB3F RETN
```

- Currently will not detect that
- Only that function should return there
- Should be able to determine these pairs during initial analysis time



Smarter Ways

- Debugger?
- Detours?
- Monitor Last Branch MSRs?



Thanks!

- Contact me
  - @trogdorsey

- The Code
  - https://github.com/trogdorsey/rop

- Further Reading
  - https://software.intel.com/en-us/articles/pin-a-dynamic-binary-instrumentation-tool
  - https://code.google.com/p/pyew/
  - http://www.cs.columbia.edu/~vpappas/papers/kbouncer.pdf
  - https://users.ece.cmu.edu/~zongweiz/media/ropecker.pdf
  - https://www.blackhat.com/us-14/briefings.html#the-beast-is-in-your-memory-return-oriented-programming-attacks-against-modern-control-flow-integrity-protection-techniques