# Geometry of Innocent Flesh on the Bone

## Return-into-libc without function Calls (on the x86)

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1. Introduction
   - Background
   - Existing vulnerabilities
2. Building Blocks for Attack
   - Intel x86 ISA
   - Using Sequences in Crafting an Attack
3. Useful Instruction Sequences
   - Useful instructions
   - Boring instructions
4. Return-Oriented Programming
   - Progressing through instructions
   - Example gadgets
5. Return-Oriented Shellcode
6. Conclusion

## Definition (Exploit)

*[When an attacker] subverts a program's control flow such that that it performs actions of his choice with its credentials.*

# Traditional Vulnerabilities

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- Format string vulnerabilities

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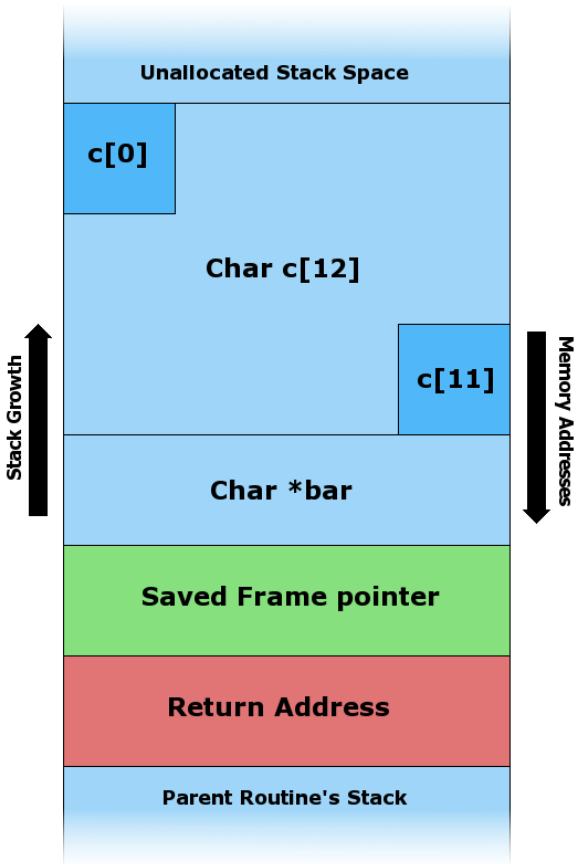
This paper targets the second goal of an attacker.

# Traditional Stack Smashing Attack



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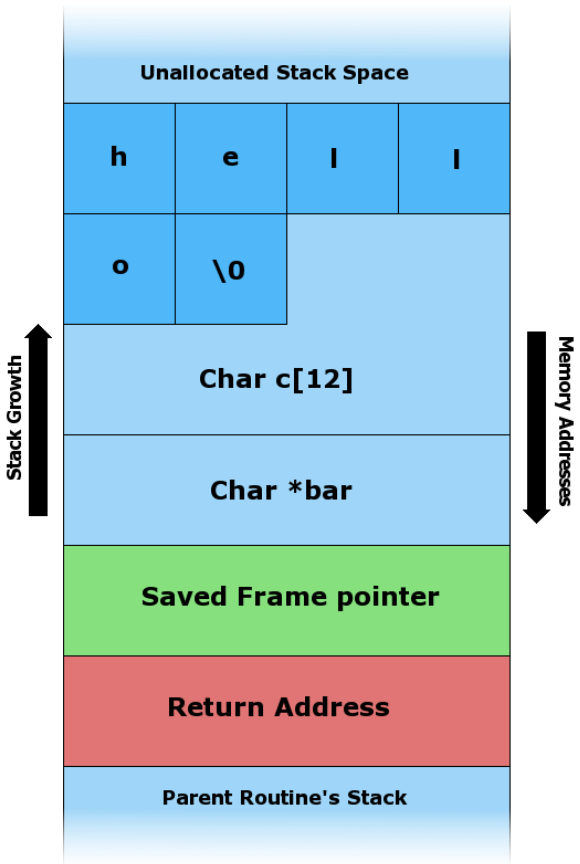

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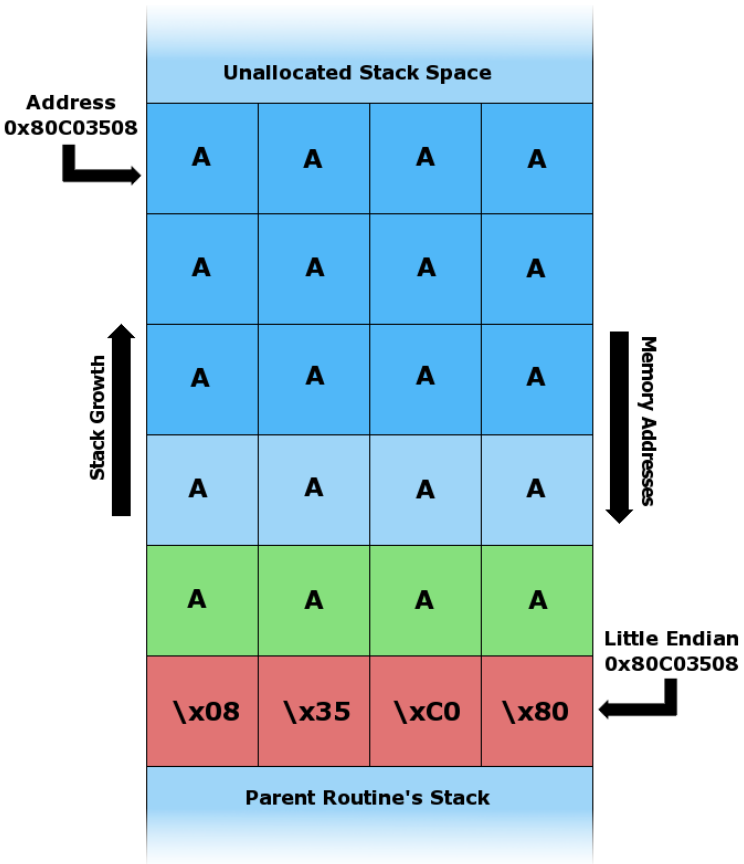

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- $W \oplus X$: No memory is both W and X.
  - Cannot inject code to be executed
  - Exists in OpenBSD and patched into Linux as part of PAX
  - Added to AMD and Intel as "NX" and "XD" respectively as a per-page execution disable

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> *Any Unix-like operating system needs a C library: the library which defines the "system calls" and other basic facilities such as open, malloc, printf, exit...*

In principle any code available can be used

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1. Attacker can only execute straight-line code
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While the above can weaken attackers, this paper shows a new ret-to-libc attack that allows arbitrary executions

# Compared to libc

- Traditional ret-to-libc attacks are built on functions that exist in the program.
- This attack is based on short code sequences, two or three instructions long.
- Some are present despite not being placed in the code without the compiler

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- Processor knows where to start and continue
- A random byte stream is very likely to be interpreted as valid

# Concrete example

Listing 1: Two instructions in ecb_crypt entrypoint

```
f7 c7 07 00 00 00        test $0x00000007 %edi
0f 95 45 c3              setnzb -61(%ebp)
```

Listing 2: Same instructions starting one byte later

```
c7 07 00 00 00 0f        movl $0x0f000000,(%edi)
95                       xchg %ebp, %eax
45                       inc %ebp
c3                       ret
```

# Concrete example

Listing 3: Two instructions in ecb_crypt entrypoint

```
f7 c7 07 00 00 00        test $0x00000007 %edi
0f 95 45 c3              setnzb -61(%ebp)
```

Listing 4: Same instructions starting one byte later

```
c7 07 00 00 00 0f        movl $0x0f000000,(%edi)
95                       xchg %ebp, %eax
45                       inc %ebp
c3                       ret
```

Static analysis can find sequences of useful instructions

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Previous attacks used pop %reg; ret to set registers to chain function calls.

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Previous attacks used pop %reg; ret to set registers to chain function calls. Gadgets are Turing complete!

## Definition (Useful)

*A sequence if useful if it could be used in a gadget.*
*i.e. it is a sequence of valid instructions ending in a ret.*

## Definition (Boring)

*An instruction is "boring" if it is either*

1. *a leave and followed by a ret*
2. *a pop %ebp followed immediately by a ret*
3. *a return or an unconditional jump*

**Theorem**

*If "a;b;c;ret" exists then "b;c;ret" must also exist.*

# ESP is the new EIP

Instead of the instruction pointer being automatically incremented to gain the new instruction, the stack pointer determines the next gadget. ESP is incremented every time there is a "ret" instruction.

# Memory Manipulation

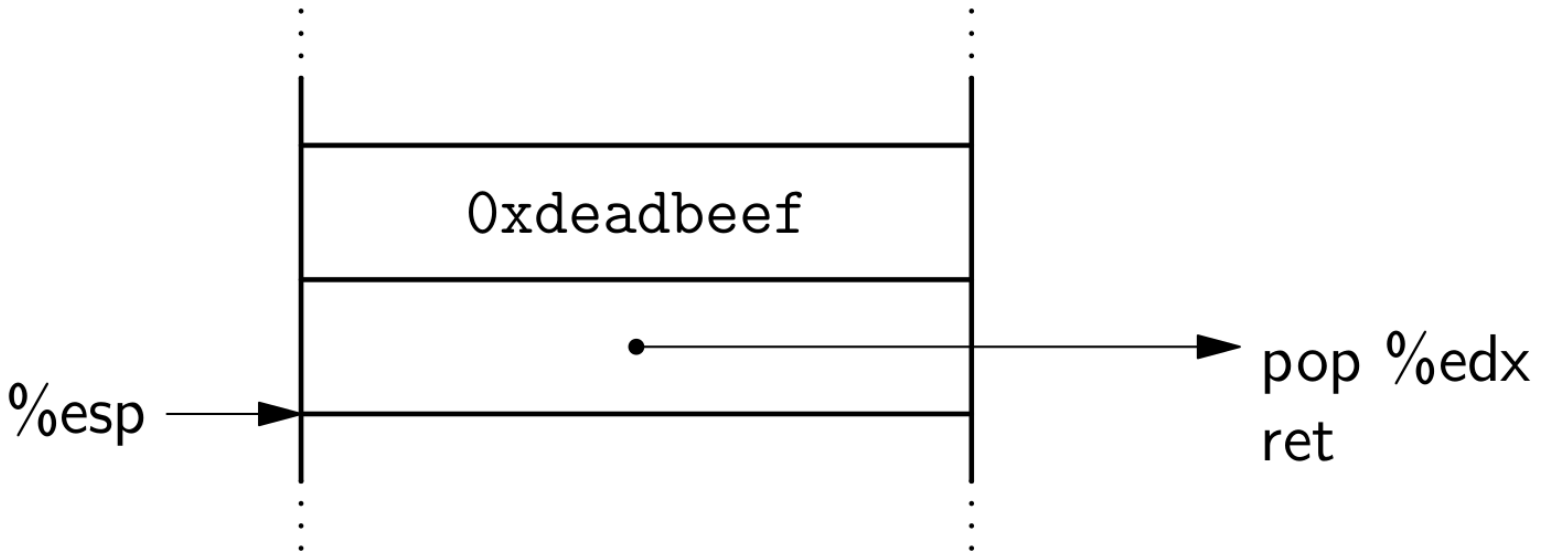


Figure 2: Load the constant `0xdeadbeef` into %edx.

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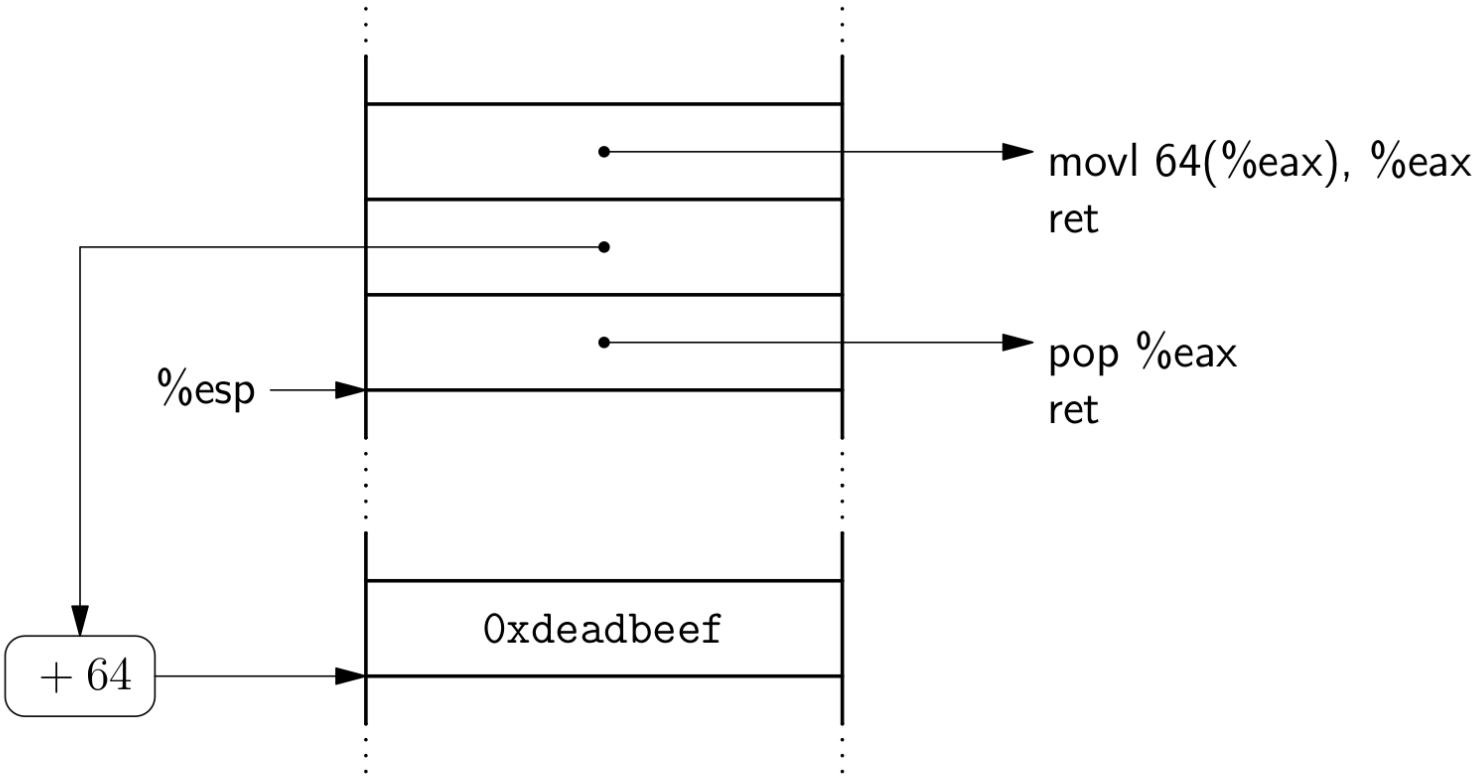


Figure 3: Load a word in memory into %eax.

# Memory Manipulation

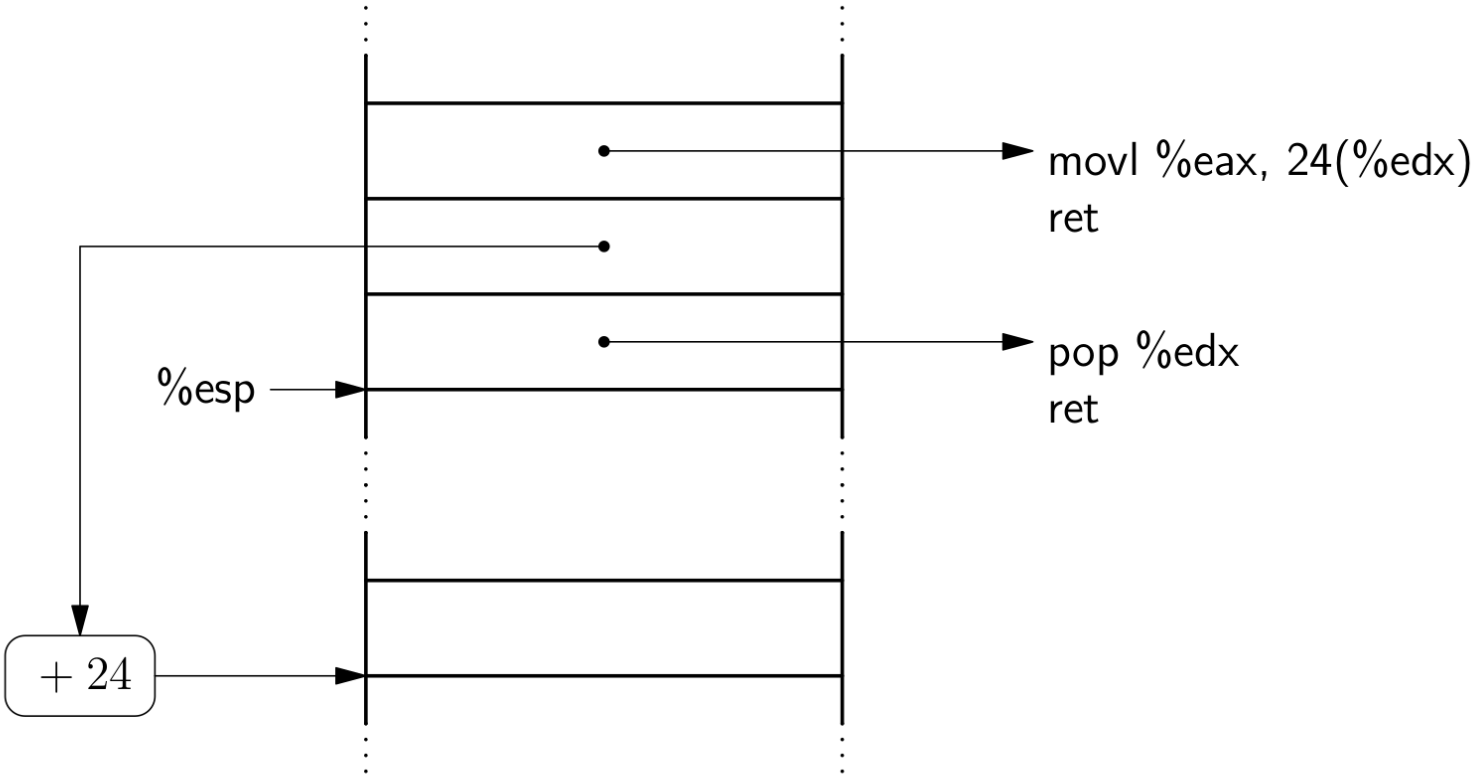


Figure 4: Store %eax to a word in memory.

# ALU operations

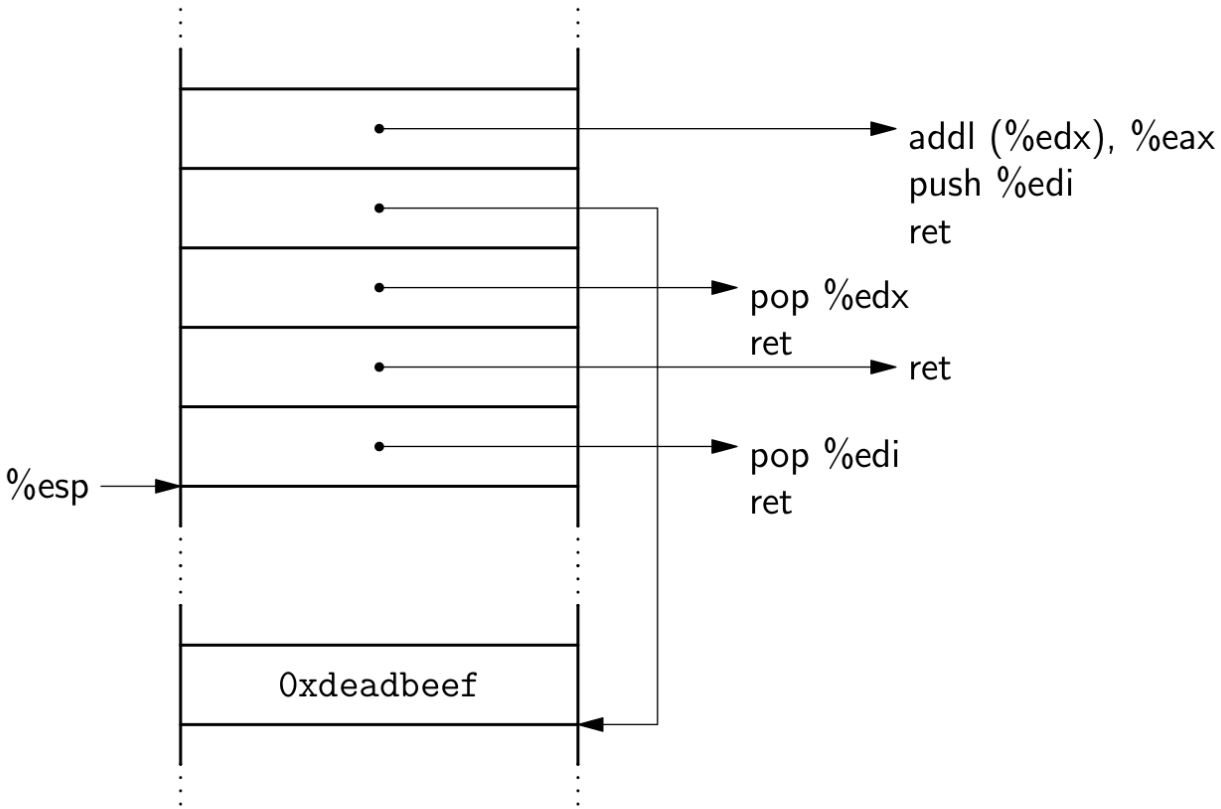


Figure 5: Simple add into %eax.

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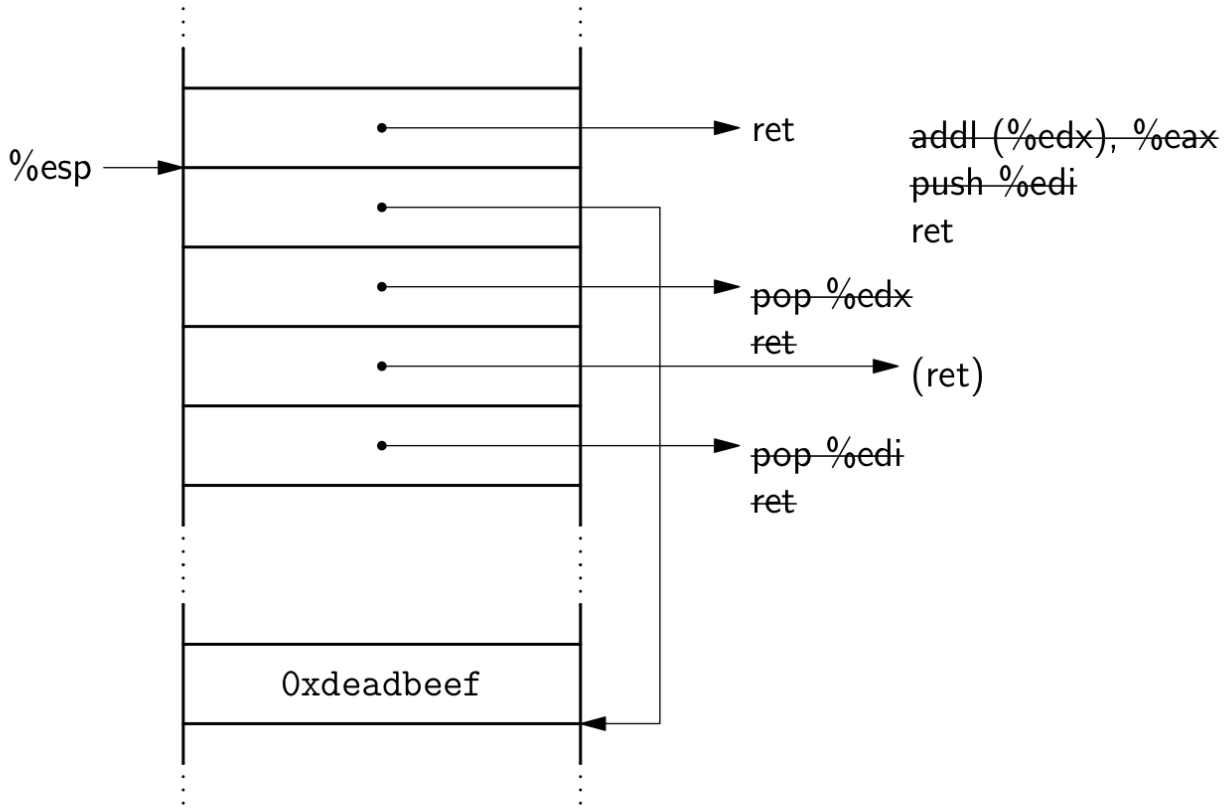


Figure 6: Simple add into %eax: State after push %edi is executed.

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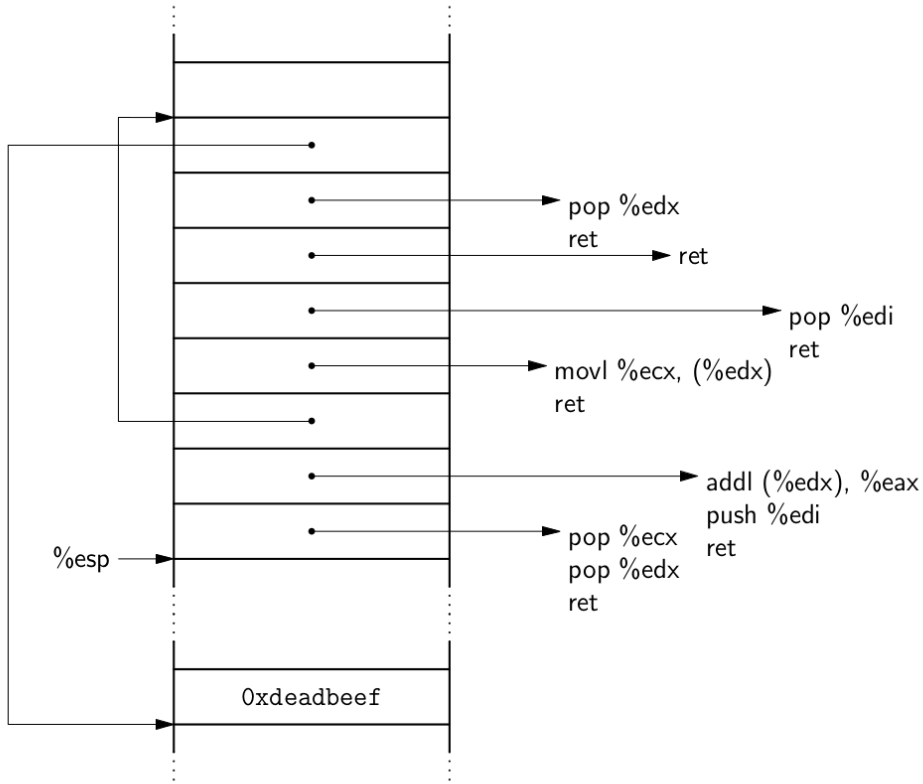


Figure 7: Repeatable add into %eax.

# Control Flow

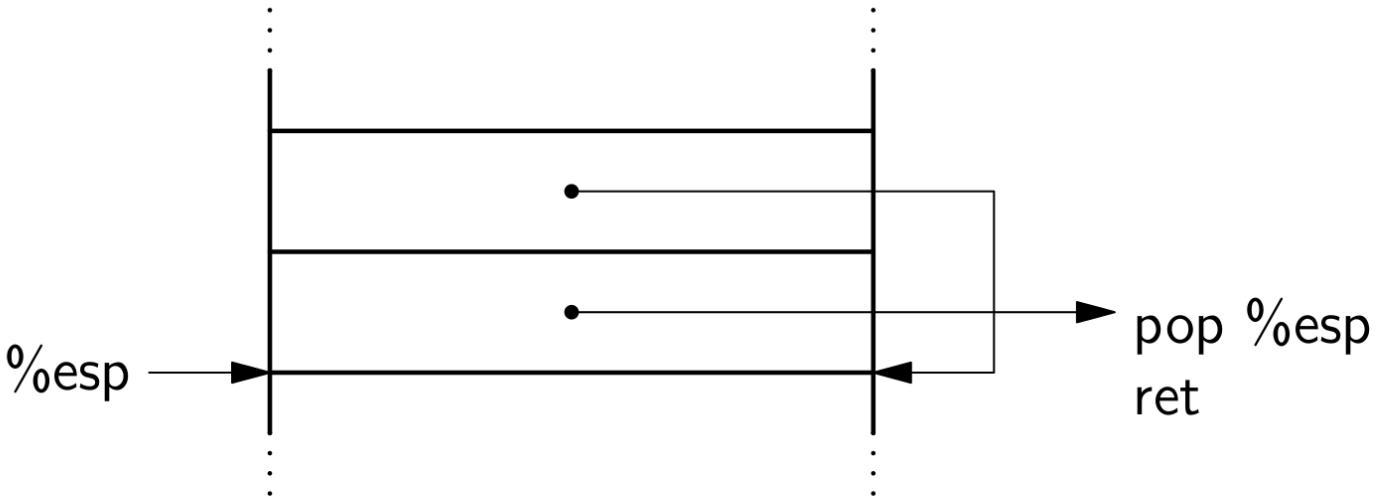


Figure 10: An infinite loop by means of an unconditional jump.

# Getting to /bin/sh

Here is where we write our exploit

# ShellCode

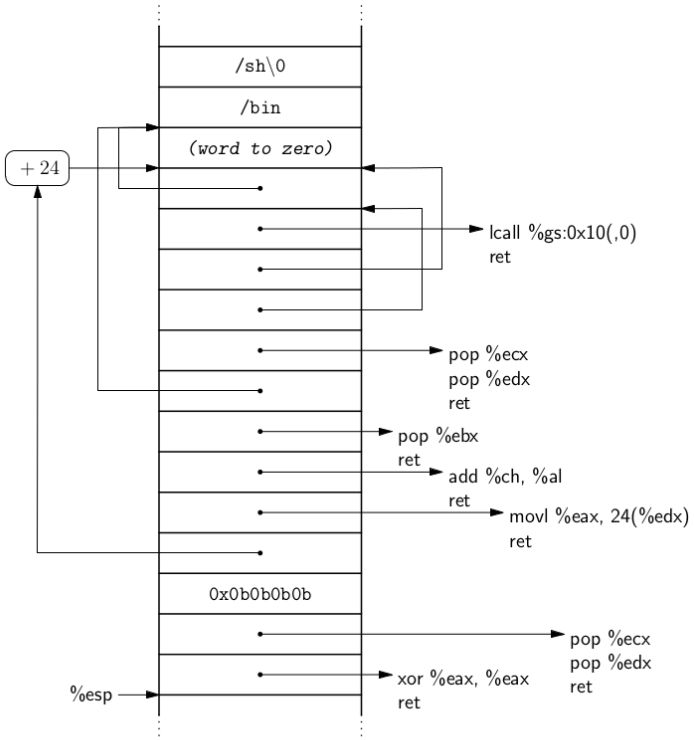


Figure 16: Shellcode.

- 1 sets %eax to zero.
- 2-4 load %edx to addr. of second word in argv, load into %ecx 0b
- 5 sets argv[1] to zero.
- 6 sets %eax to 0x0b
- 7-8 point %ebx to "/bin/sh"
- 9-11 set %ecx to address of argv[], %edx to address of envp[]
- 12 traps into kernel

# References I

Hovav Shacham, *The geometry of innocent flesh on the bone: Return-into-libc without function calls (on the x86)*, Proceedings of CCS 2007 (Sabrina De Capitani di Vimercati and Paul Syverson, eds.), ACM Press, October 2007, pp. 552–61.

Wikipedia, *Stack buffer overflow — wikipedia, the free encyclopedia*, 2015, [Online; accessed 5-October-2015].