Memory Corruption - SUMMARY*

- IA32
- Types of vulnerabilities
- Stack overflow

*These slides were adapted from previous presentations by Valerio Costamagna (University of Torino) and from the book “The Art of Software Security Assessment” by M. Dowd, J. McDonald and J. Schuh – Addison Wesley.

Part 1

1. richiami architettura IA32/x86
2. principali istruzioni assembler
3. stack
4. examples

ia32

intro IA32/x86

Architettura IA32/x86

- Intel architecture: versione 32 bit del x86 Instruction Set Architecture (ISA)
- arch CISC: istruzioni di lunghezza variabile, diverse istruzioni per accedere/modificare la memoria
- 8 registri 32 bit *general purpose*: EAX, EBX, ECX, EDX, ESI, EDI, EBP, ESP
- 6 registri 16 bit *segment register*: CS, DS, ES, FS, GS, SS
- diversi registri speciali
- little endian

Table: Registri principali

Nome	Descrizione
EBP	stack pointer
ESP	frame pointer
EIP	instruction pointer
EFLAGS	*bit flags*
ESI	source string/mem operations
EDI	dest string/mem operations
ECX	counter in loops
EAX	valore di return di una funzione

Nomenclatura

ABI

Application Binary Interface: descrive l'interfaccia tra il SO e i binari su una particolare architettura. Determina la *calling convention* (come vengono chiamate le funzioni), come vengono gestite le syscall, etc…

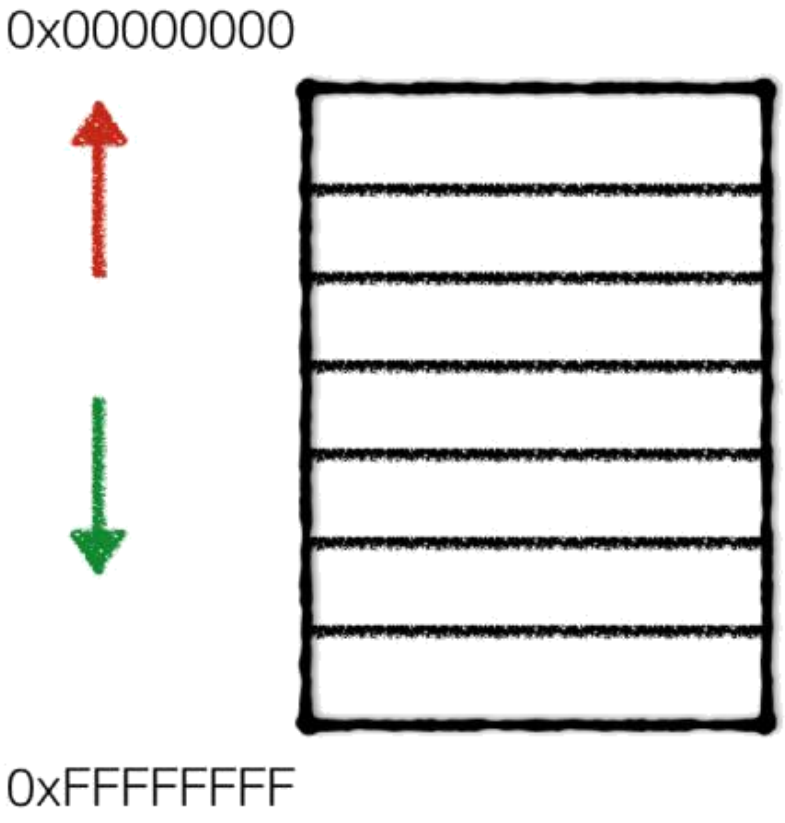
ILP32

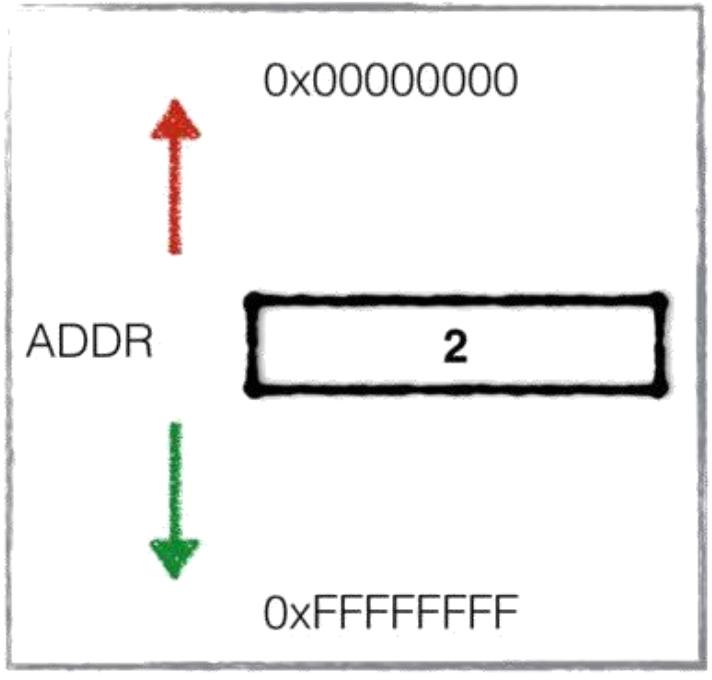
Data model in cui i tipi *Int* = *long* = *pointer* occupano 32 bit di memoria

stack

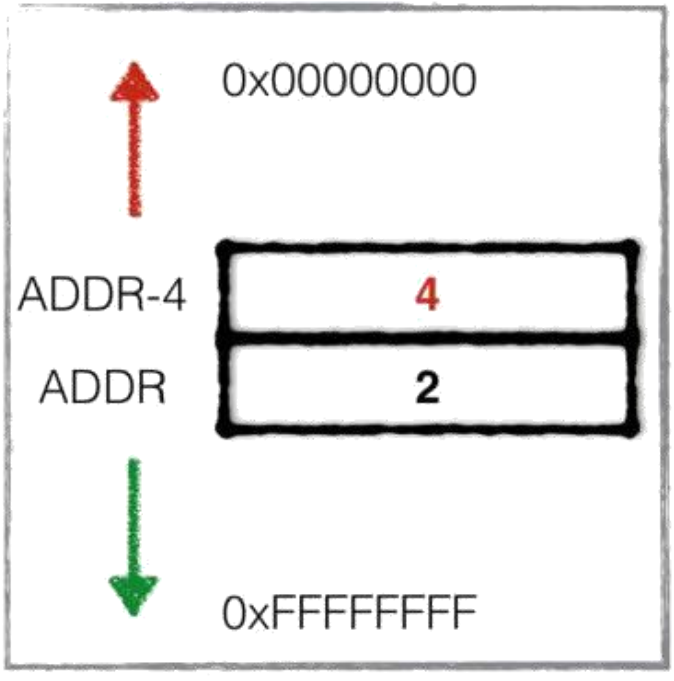
Stack

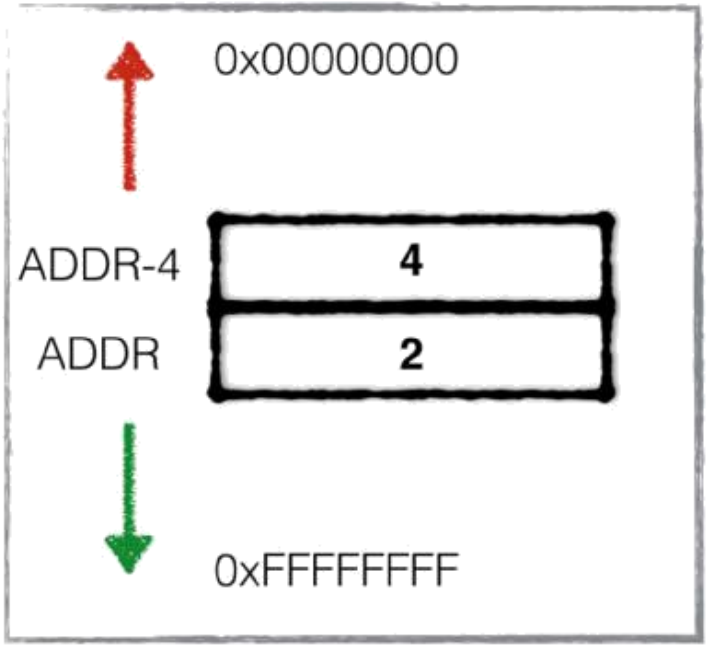
- Struttura dati usata per salvare ed ottenere una serie di elementi
- Last In First Out (LIFO)
- Cresce verso indirizzi di memoria bassi!
- Due operazioni possibili:
  - PUSH() : inserisce un elemento in cima (top)
  - POP() : ritorna e rimuove l'elemento dalla cima (top)



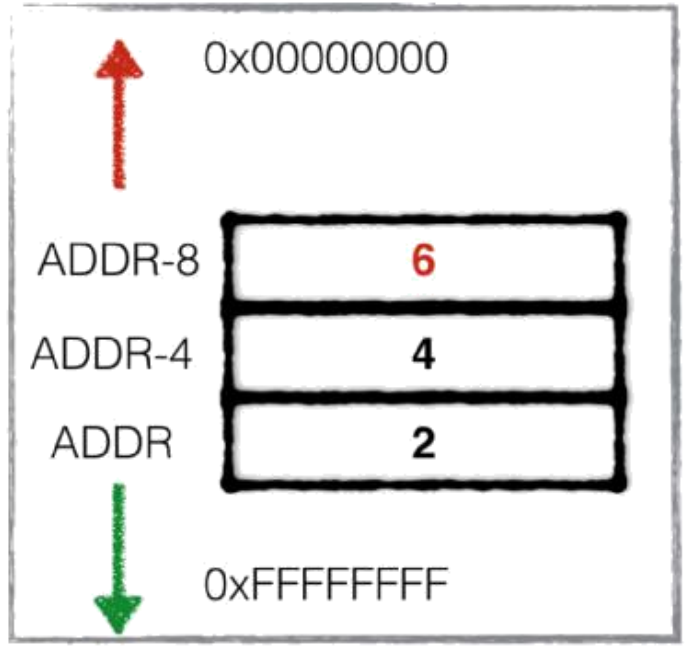

0x00000000
ADDR
2
0xFFFFFFFF

PUSH #4

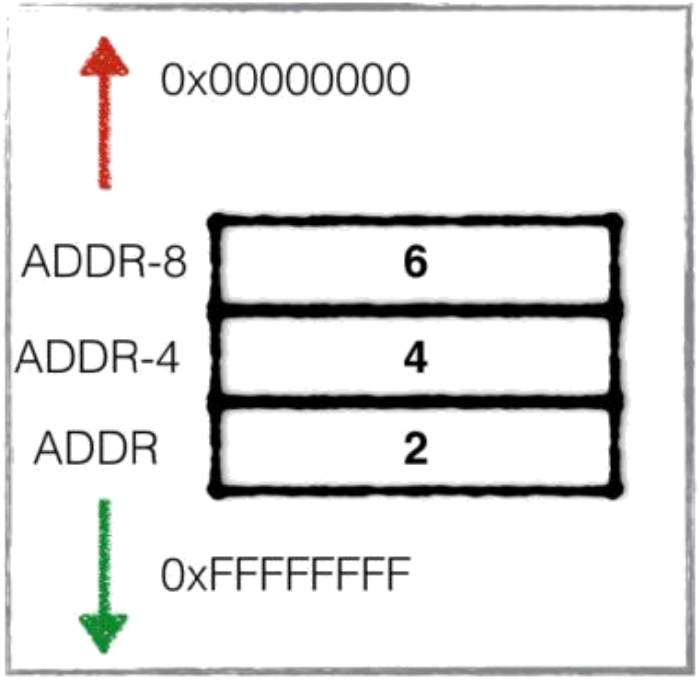

0x00000000
ADDR-4
4
ADDR
2
0xFFFFFFFF

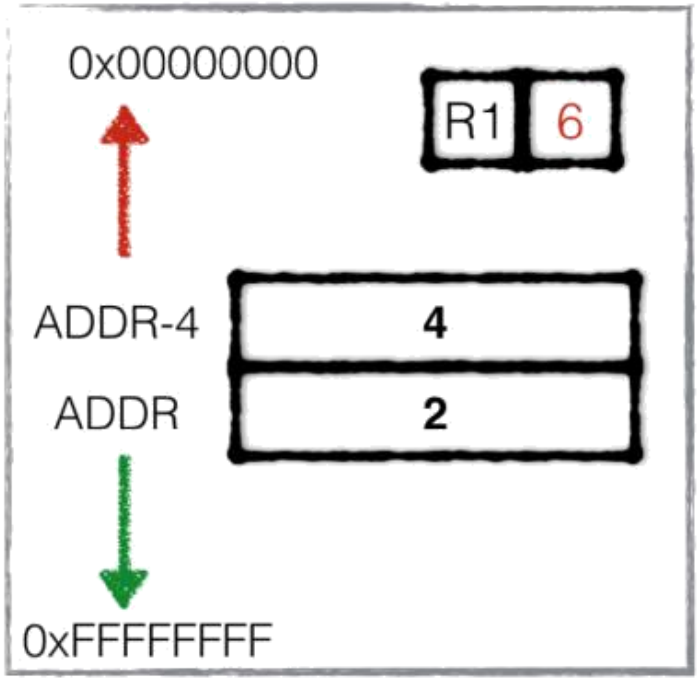

0x00000000
ADDR-4
4
ADDR
2
0xFFFFFFFF

PUSH #6

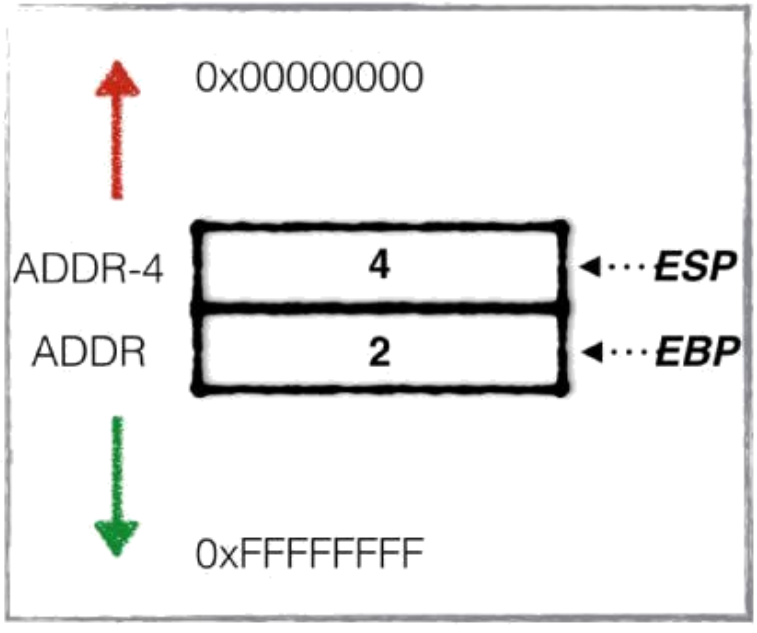

0x00000000
ADDR-8
6
ADDR-4
4
ADDR
2
0xFFFFFFFF

POP R1

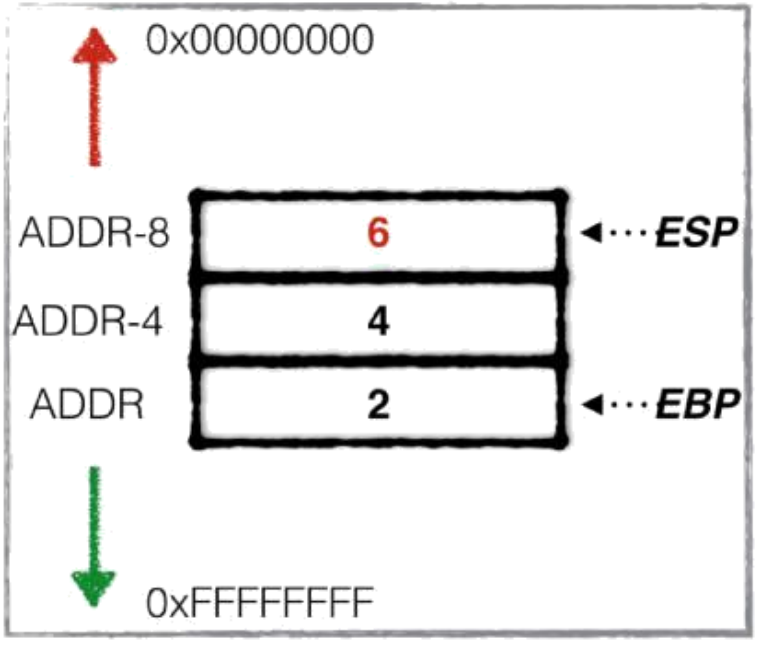

0x00000000
ADDR-8
6
ADDR-4
4
ADDR
2
0xFFFFFFFF

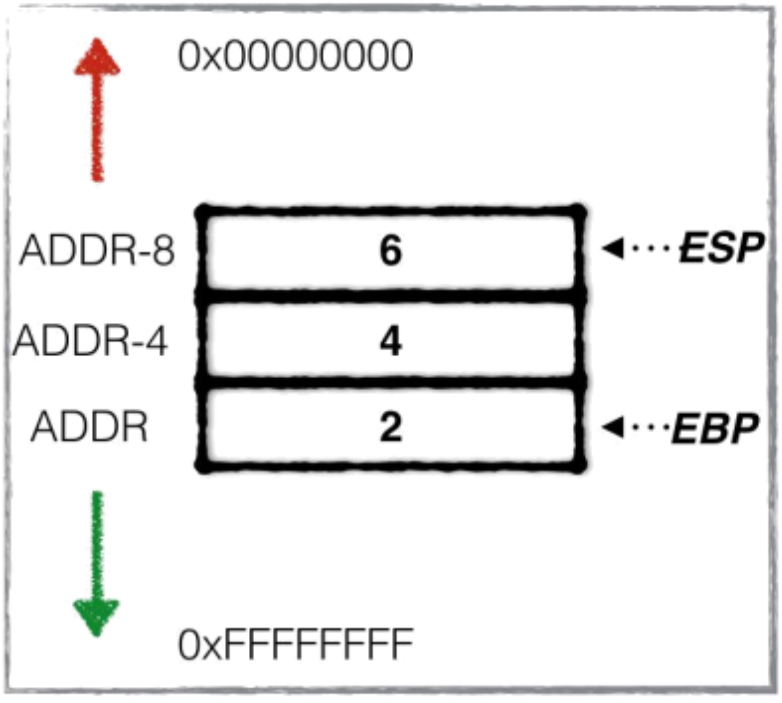

0x00000000
R1
6
ADDR-4
4
ADDR
2
0xFFFFFFFF

Stack pointer e Base Pointer Registers

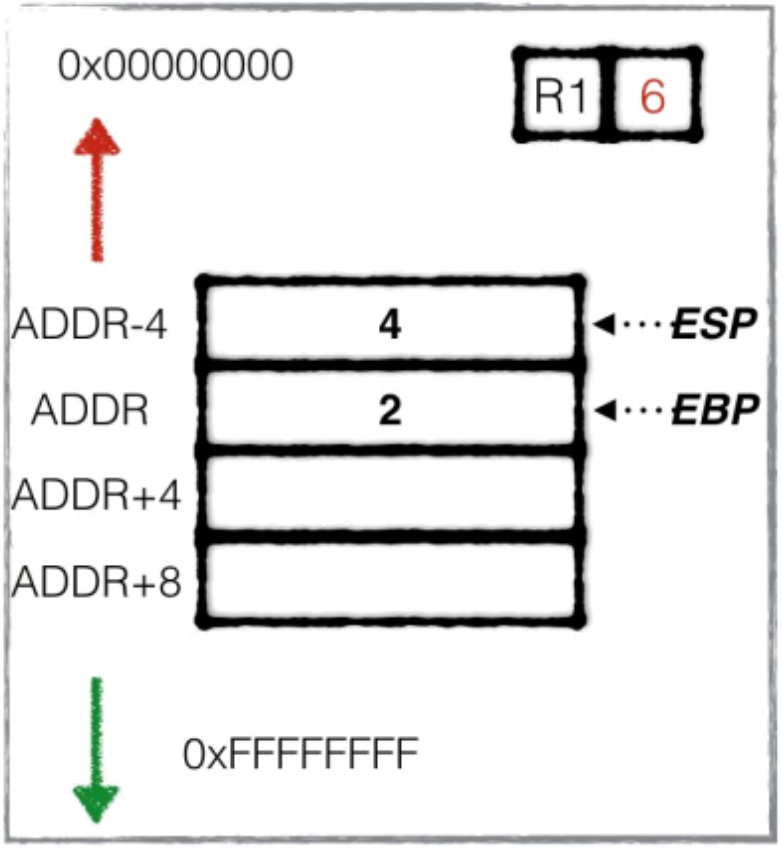


PUSH #6




0x00000000
ADDR-8
6
ESP
ADDR-4
4
ADDR
2
EBP
0xFFFFFFFF

POP R1


0x00000000
R1
6
ADDR-4
4
ESP
ADDR
2
EBP
ADDR+4
ADDR+8
0xFFFFFFFF

Ogni funzione ha un proprio *stack frame*, compreso tra EBP e ESP, in cui memorizza:

- variabili locali
- machine state (indirizzo di ritorno, old EBP)
- parametri delle chiamate a funzioni

Il registro EBP viene utilizzato (se non specificato diversamente a compile time) come *base* per accedere alle variabili locali dello *stack frame*.

```
1  int function_B(int a, int b)
2  {
3      int x, y;
4      x = a * a;
5      y = b * b;
6      return (x + y);
7  }
8  int function_A(int p, int q)
9  {
10     int c;
11     c = function_B(p,q);
12     return c;
13 }
14 int main(int argc, char** argv, char** envp)
15 {
16     int ret;
17     ret = function_A(1,2);
18     return ret;
19 }
```

Stack

function_B code:

```
1  int function_B(int a, int b)
2  {
3  int x, y;
4      x = a * a;
5      y = b * b;
6      return x + y;
7  }
8
```

Assembler code:

```
1  <+0>:  push   ebp
2  <+1>:  mov    ebp,esp
3  <+3>:  sub    esp,0x10
4  <+6>:  mov    eax,DWORD PTR [ebp+0x8]
5  <+9>:  imul   eax,DWORD PTR [ebp+0x8]
6  <+13>: mov    DWORD PTR [ebp-0x4],eax
7  <+16>: mov    eax,DWORD PTR [ebp+0xc]
8  <+19>: imul   eax,DWORD PTR [ebp+0xc]
9  <+23>: mov    DWORD PTR [ebp-0x8],eax
10 <+26>: mov    eax,DWORD PTR [ebp-0x8]
11 <+29>: mov    edx,DWORD PTR [ebp-0x4]
12 <+32>: add    eax,edx
13 <+34>: leave
14 <+35>: ret
15
```

Stack

function_A code:

```
1  int function_A(int p, int q){
2   int c;
3       c = function_B(p,q);
4       return c;
5  }
6
```

Assembler code:

```
1  <+0>:  push   ebp
2  <+1>:  mov    ebp,esp
3  <+3>:  sub    esp,0x18
4  <+6>:  mov    eax,DWORD PTR [ebp+0xc]
5  <+9>:  mov    DWORD PTR [esp+0x4],eax
6  <+13>: mov    eax,DWORD PTR [ebp+0x8]
7  <+16>: mov    DWORD PTR [esp],eax
8  <+19>: call   0x80483ed <function_B>
9  <+24>: mov    DWORD PTR [ebp-0x4],eax
10 <+27>: mov    eax,DWORD PTR [ebp-0x4]
11 <+30>: leave
12 <+31>: ret
13
```

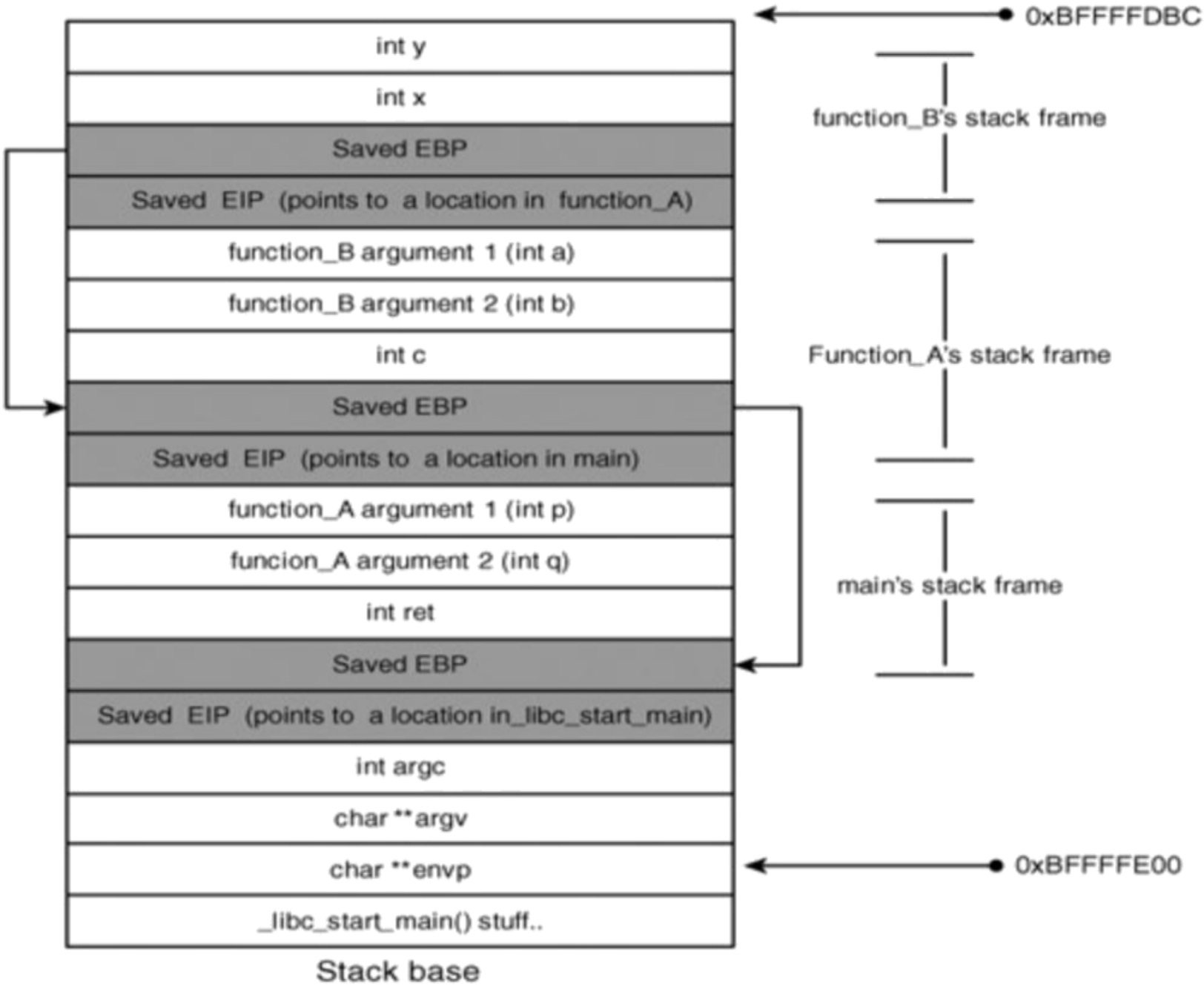
Stack

main code:

```
1  int main(int argc, char** argv, char**
       envp){
2  int ret;
3      ret = function_A(1,2);
4      return ret;
5  }
6
```

Assembler code:

```
1  <+0>:  push   ebp
2  <+1>:  mov    ebp,esp
3  <+3>:  sub    esp,0x18
4  <+6>:  mov    DWORD PTR [esp+0x4],0x2
5  <+14>: mov    DWORD PTR [esp],0x1
6  <+21>: call   0x8048411 <function_A>
7  <+26>: mov    DWORD PTR [ebp-0x4],eax
8  <+29>: mov    eax,DWORD PTR [ebp-0x4]
9  <+32>: leave
10 <+33>: ret
11
```


0xBFFFFDBC
int y
int x
Saved EBP
Saved EIP (points to a location in function_A)
function_B argument 1 (int a)
function_B argument 2 (int b)
int c
Saved EBP
Saved EIP (points to a location in main)
function_A argument 1 (int p)
funcion_A argument 2 (int q)
int ret
Saved EBP
Saved EIP (points to a location in_libc_start_main)
int argc
char **argv
char **envp
_libc_start_main() stuff..
0xBFFFFE00
function_B's stack frame
Function_A's stack frame
main's stack frame
Stack base

Function Prologue

```
1 <+0>:  push   ebp
2 <+1>:  mov    ebp,esp
3 <+3>:  sub    esp,VALORE
```

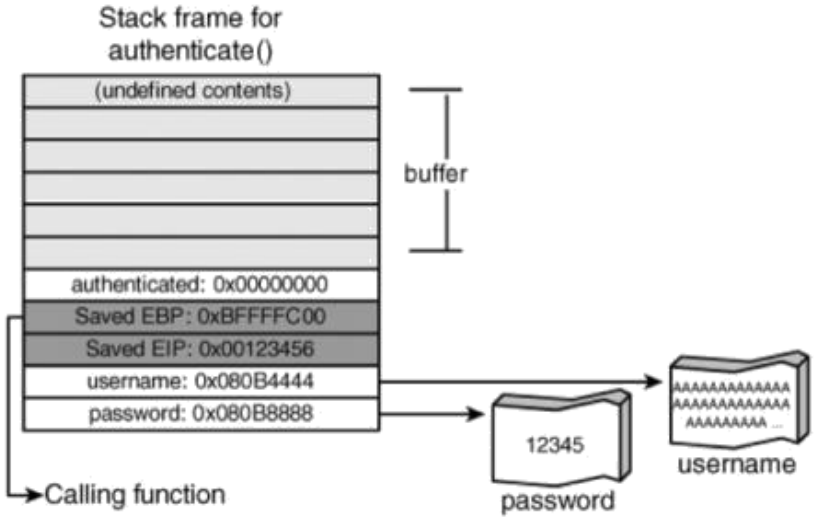
Function Epilogue

```
1 mov   esp, ebp
2 pop   ebp
3 ret
```

Stack abuse

```
1 int authenticate(char *username, char* password)
2     {
3         int authenticated;
4         char buffer[1024];
5
6         authenticated = verify_password(username, password);
7
8         if(authenticated == 0) {
9            sprintf(buffer, ”password is incorrect for user: %s \n” , username);
10           log(”%s”, buffer);
11        }
12        return authenticated;
13    }
```

Stack abuse


Stack frame for
authenticate()
(undefined contents)
buffer
authenticated: 0x00000000
Saved EBP: 0xBFFFFC00
Saved EIP: 0x00123456
username: 0x080B4444
password: 0x080B8888
Calling function
12345
password
AAAAAAAAAAAA
AAAAAAAAAAAA
AAAAAAAA ...
username

buffer overflow

Un buffer overflow é un bug che si verifica quando dati copiati in una locazione di memoria eccedono la grandezza riservata per tale variabile.
Quando si verifica un overflow, i dati in eccesso vengono copiati nelle locazioni di memoria adiacenti.
I buffer overflow sono i tipi piú comuni di memory corruption.

Stack Overflow - Can you spot the bug ?

```
1  int main() {
2   int cookie;
3   char buf[80];
4   printf(”buf: %08x cookie: %08x\n”, &buf, &cookie);
5   gets(buf);
6  if (cookie == 0x41424344)
7  printf(”you win!\n”);
8   }
```

Letture consigliate

- Stack overflow: `http://insecure.org/stf/smashstack.html`
- memory binary layout: `http://www.geeksforgeeks.org/memory-layout-of-c-program/`
- x86 assembly: `http://www.drpaulcarter.com/pcasm/`

References

M. Dowd, J. McDonald and J. Schuh,
“The Art of Software Security Assessment”,
Adddison Wesley