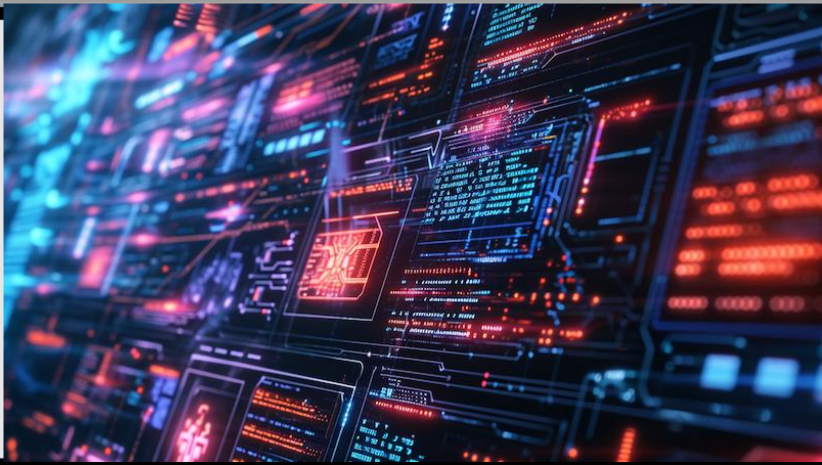
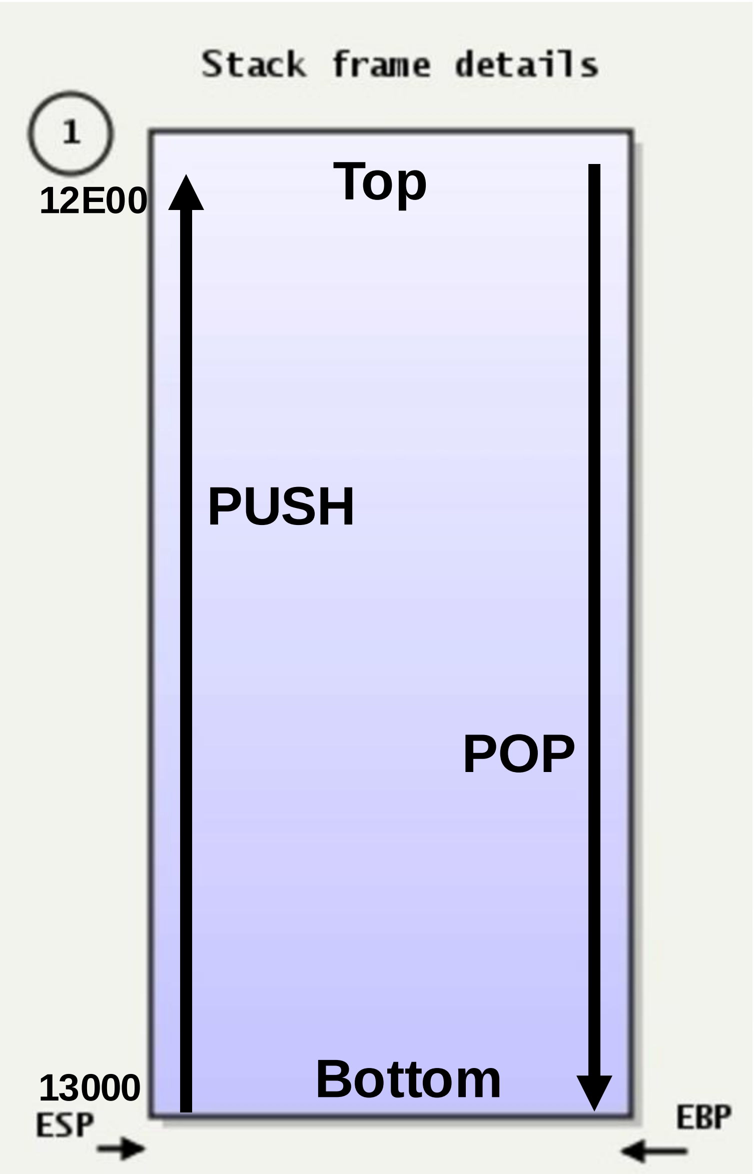
Class 5

CSC 600 Advanced Seminar
Stack Frame & Calling Convention

Si Chen (schen@wcupa.edu)



The Stack



Stack:

- A special region of your computer's memory that **stores temporary variables** created by each functions
- The stack is a "**LIFO**" (last in, first out) data structure
- Once a stack variable is freed, that region of memory becomes available for other stack variables.

Properties:

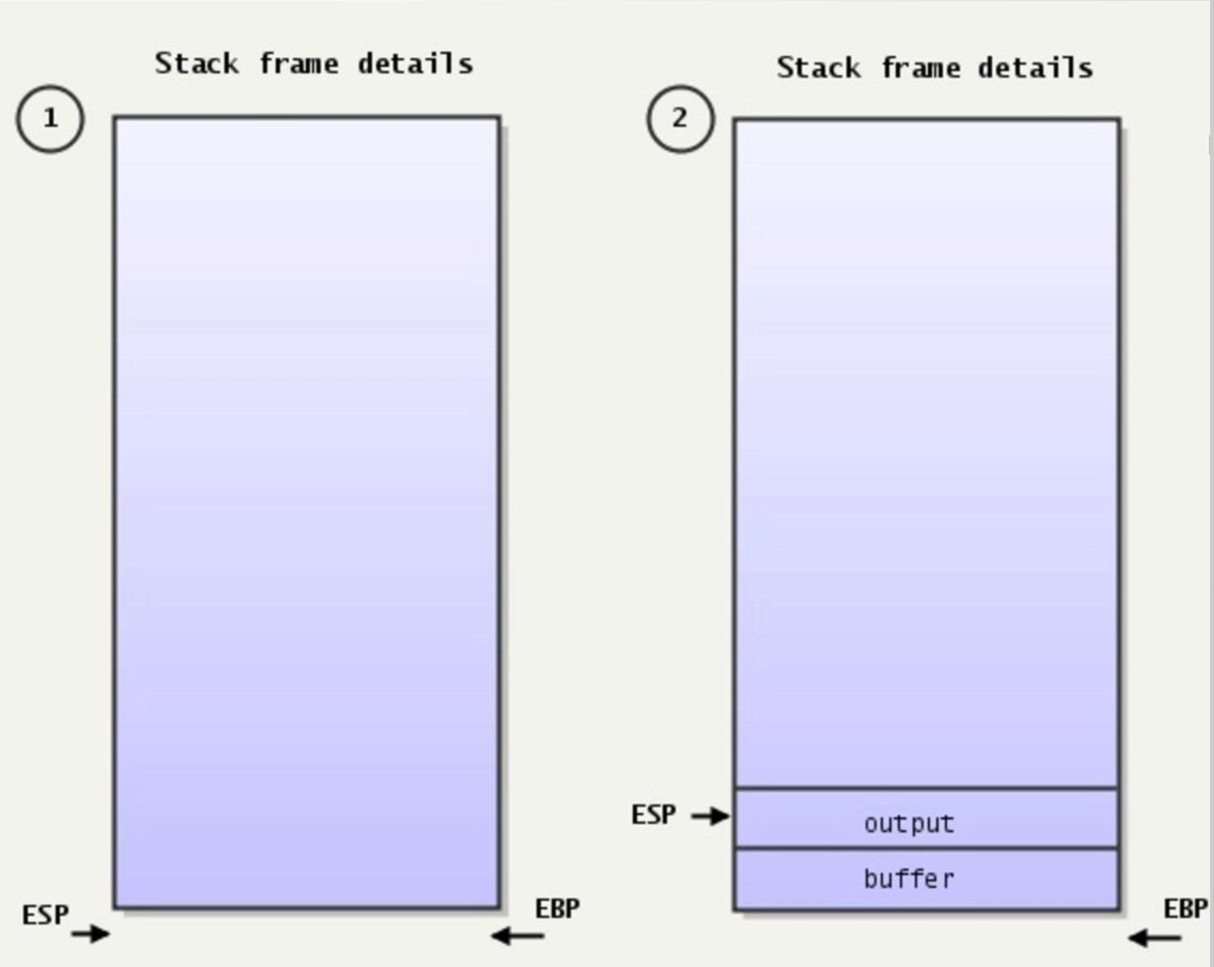
- the stack grows and shrinks as functions **push and pop** local **variables**
- there is no need to manage the memory yourself, variables are allocated and freed **automatically**
- the **stack has size limits**
- stack variables only exist while the function that created them, is running

EBP—Pointer to data on the stack
ESP—Stack pointer

The Stack

Stack:

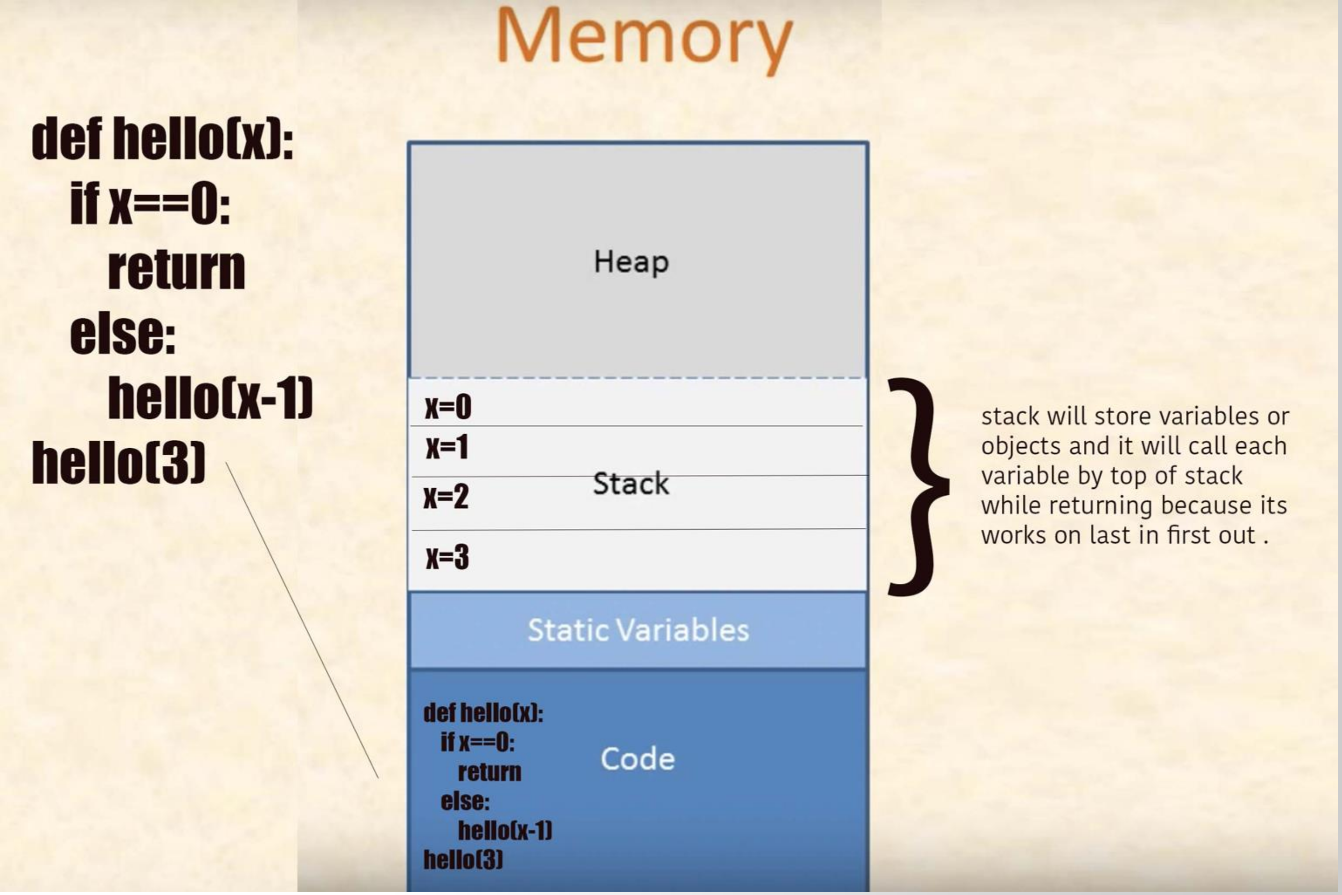
- A special region of your computer's memory that **stores temporary variables** created by each functions
- The stack is a "**LIFO**" (last in, first out) data structure
- Once a stack variable is freed, that region of memory becomes available for other stack variables.



Stack Frame

Stack Frame

- A stack frame is **a frame of data that gets pushed onto the stack**.
- In the case of a **call stack**, a stack frame would represent **a function call and its argument data**.

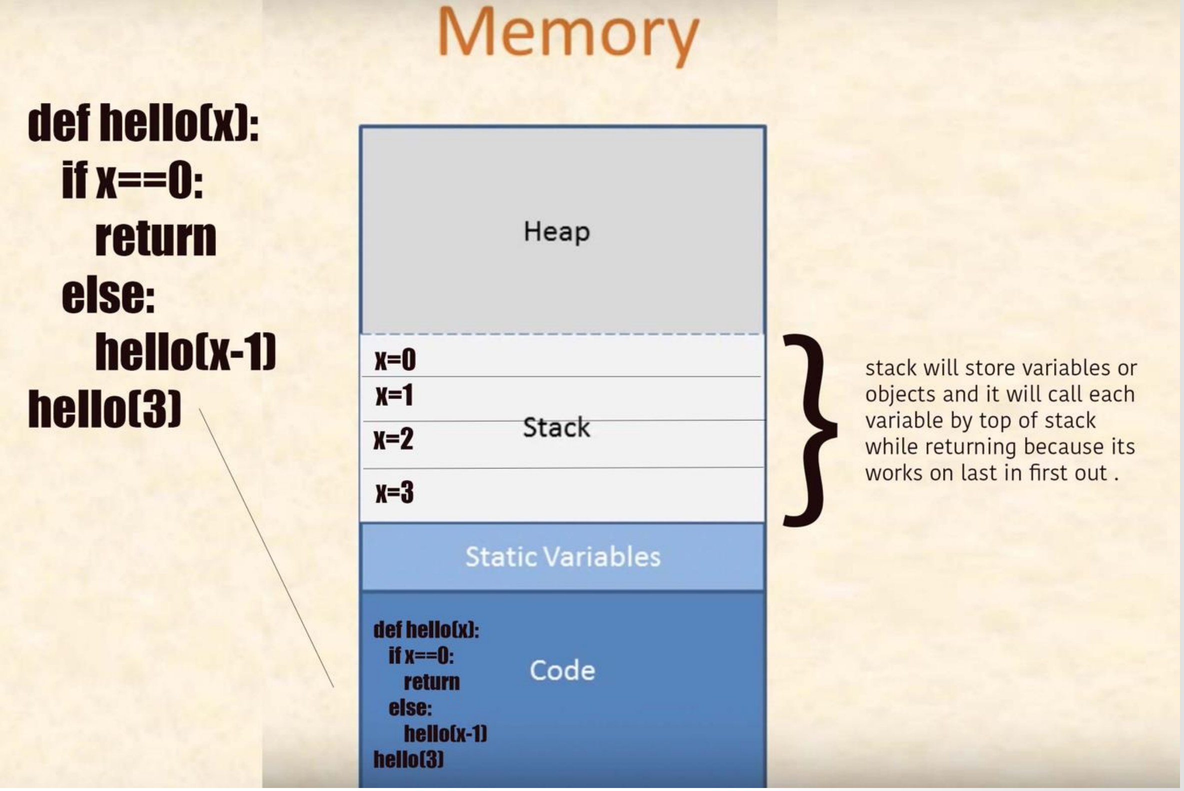


```
def hello(x):
   if x==0:
      return
   else:
      hello(x-1)
hello(3)
```

```
def hello(x):
  if x==0:
    return
  else:
    hello(x-1)
hello(3)
```

stack will store variables or objects and it will call each variable by top of stack while returning because its works on last in first out .

Stack Frame



```
def hello(x):
  if x==0:
    return
  else:
    hello(x-1)
hello(3)
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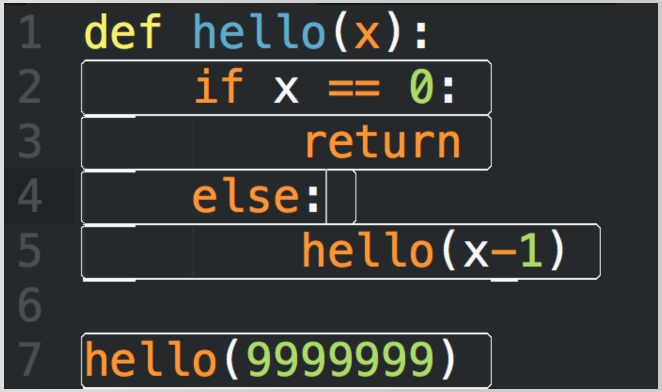
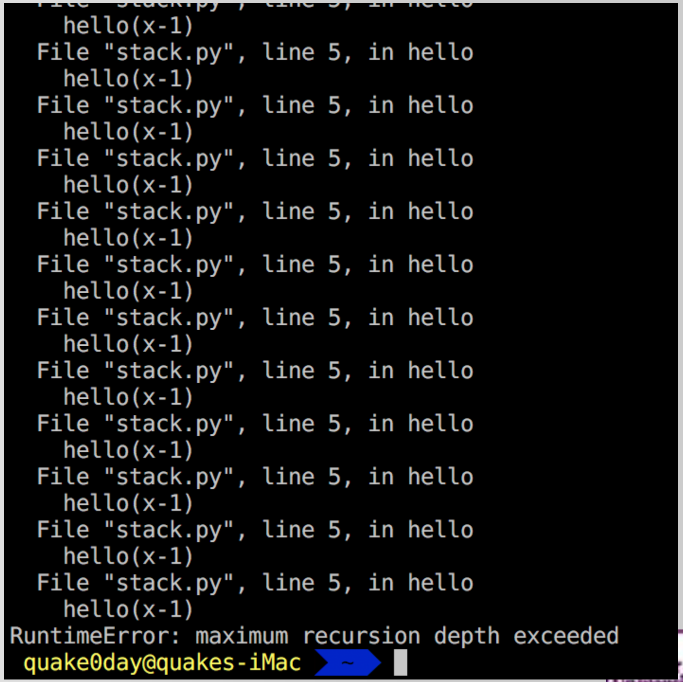
stack will store variables or objects and it will call each variable by top of stack while returning because its works on last in first out .



```
def hello(x):
    if x == 0:
        return
    else:
        hello(x-1)

hello(9999999)
```



```
  File "stack.py", line 5, in hello
    hello(x-1)
  File "stack.py", line 5, in hello
    hello(x-1)
  File "stack.py", line 5, in hello
    hello(x-1)
  File "stack.py", line 5, in hello
    hello(x-1)
  File "stack.py", line 5, in hello
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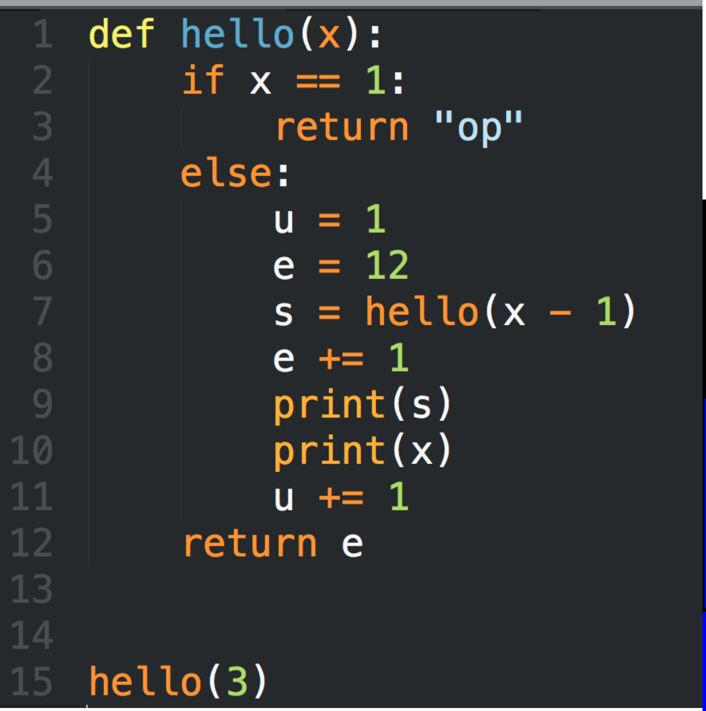
    hello(x-1)
  File "stack.py", line 5, in hello
    hello(x-1)
  File "stack.py", line 5, in hello
    hello(x-1)
  File "stack.py", line 5, in hello
    hello(x-1)
RuntimeError: maximum recursion depth exceeded
 quake0day@quakes-iMac  ~
```

Stack

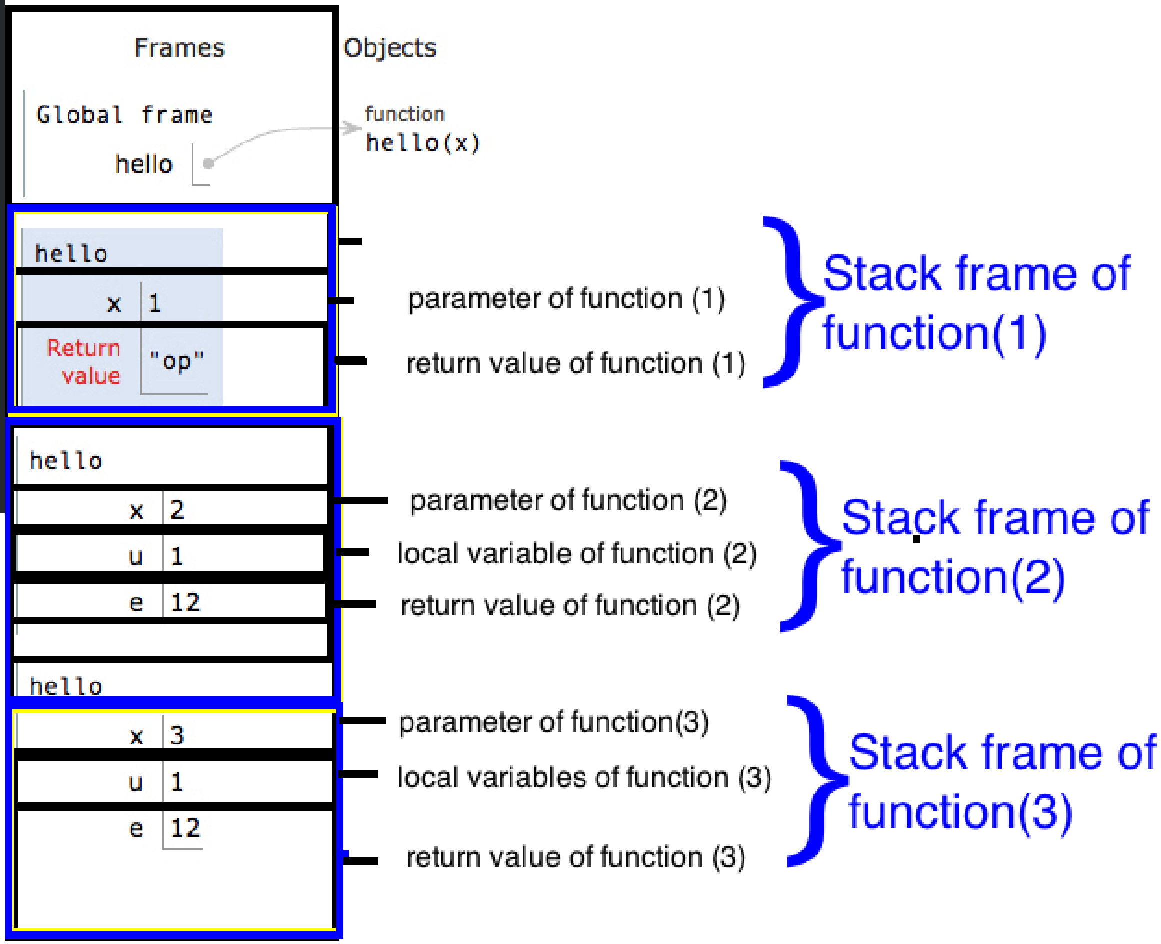
- Pass arguments
- Save the return address
- Save **local variable**

Stack Frame



```
def hello(x):
    if x == 1:
        return "op"
    else:
        u = 1
        e = 12
        s = hello(x - 1)
        e += 1
        print(s)
        print(x)
        u += 1
    return e


hello(3)
```



parameter of function (1)

return value of function (1)

Stack frame of function(1)

parameter of function (2)

local variable of function (2)

return value of function (2)

Stack frame of function(2)

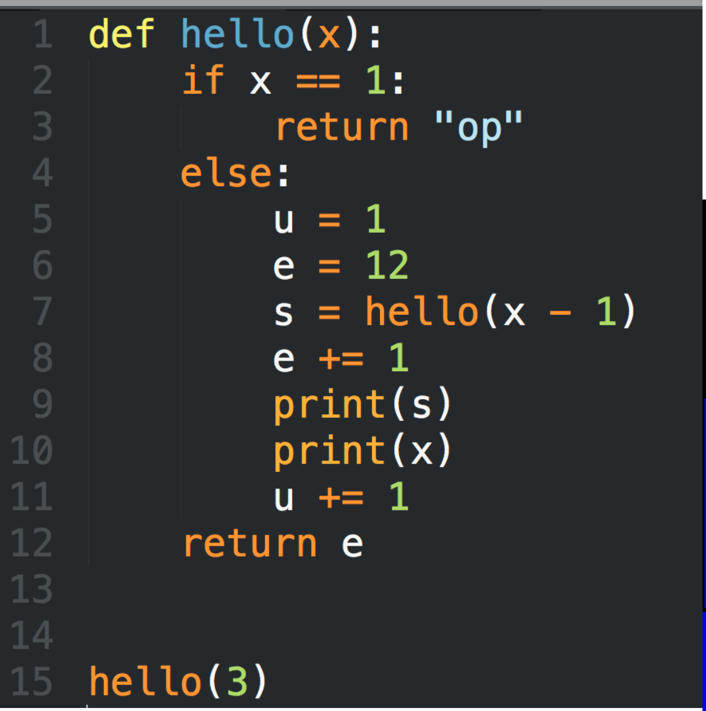
parameter of function(3)

local variables of function (3)

return value of function (3)

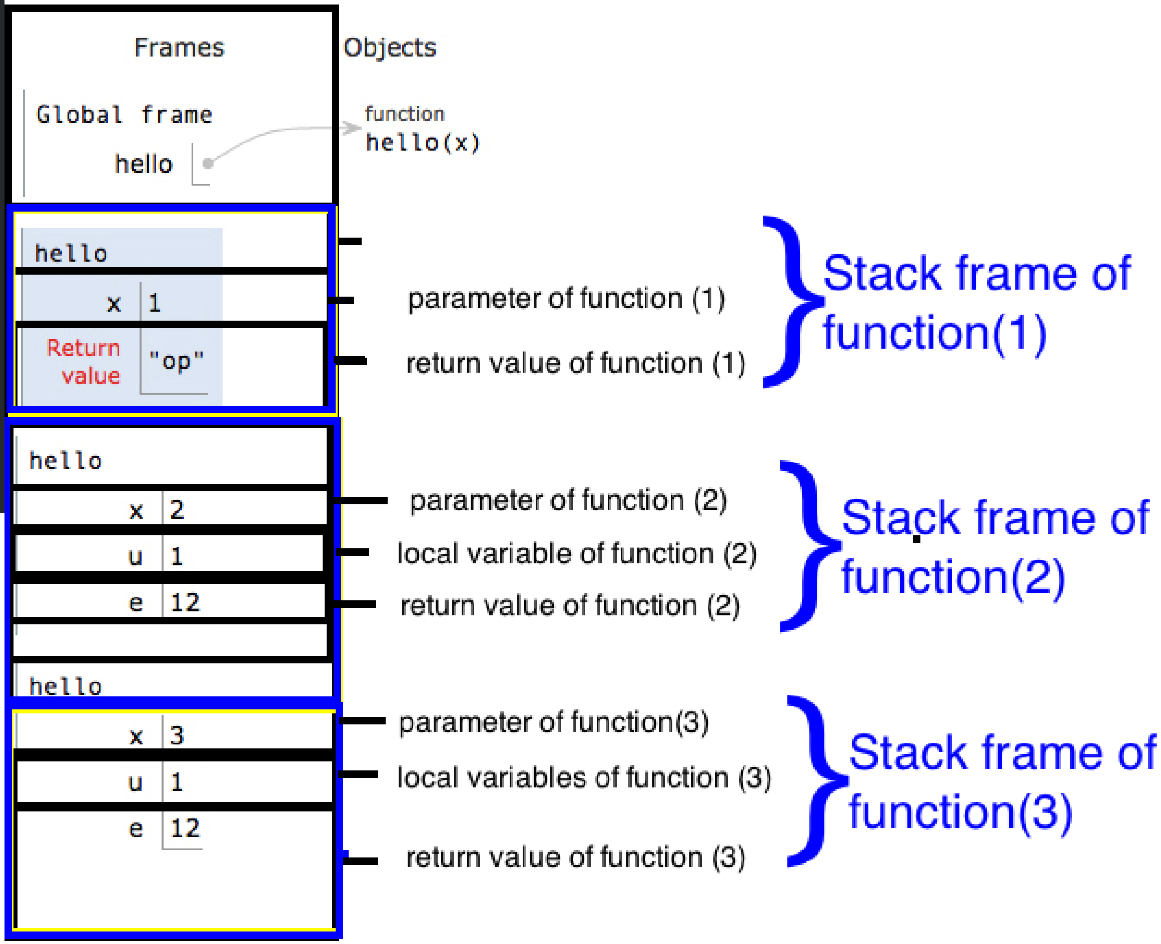
Stack frame of function(3)

Stack Frame



```python
def hello(x):
    if x == 1:
        return "op"
    else:
        u = 1
        e = 12
        s = hello(x - 1)
        e += 1
        print(s)
        print(x)
        u += 1
    return e


hello(3)
```



parameter of function (1)

return value of function (1)

Stack frame of function(1)

parameter of function (2)

local variable of function (2)

return value of function (2)

Stack frame of function(2)

parameter of function(3)

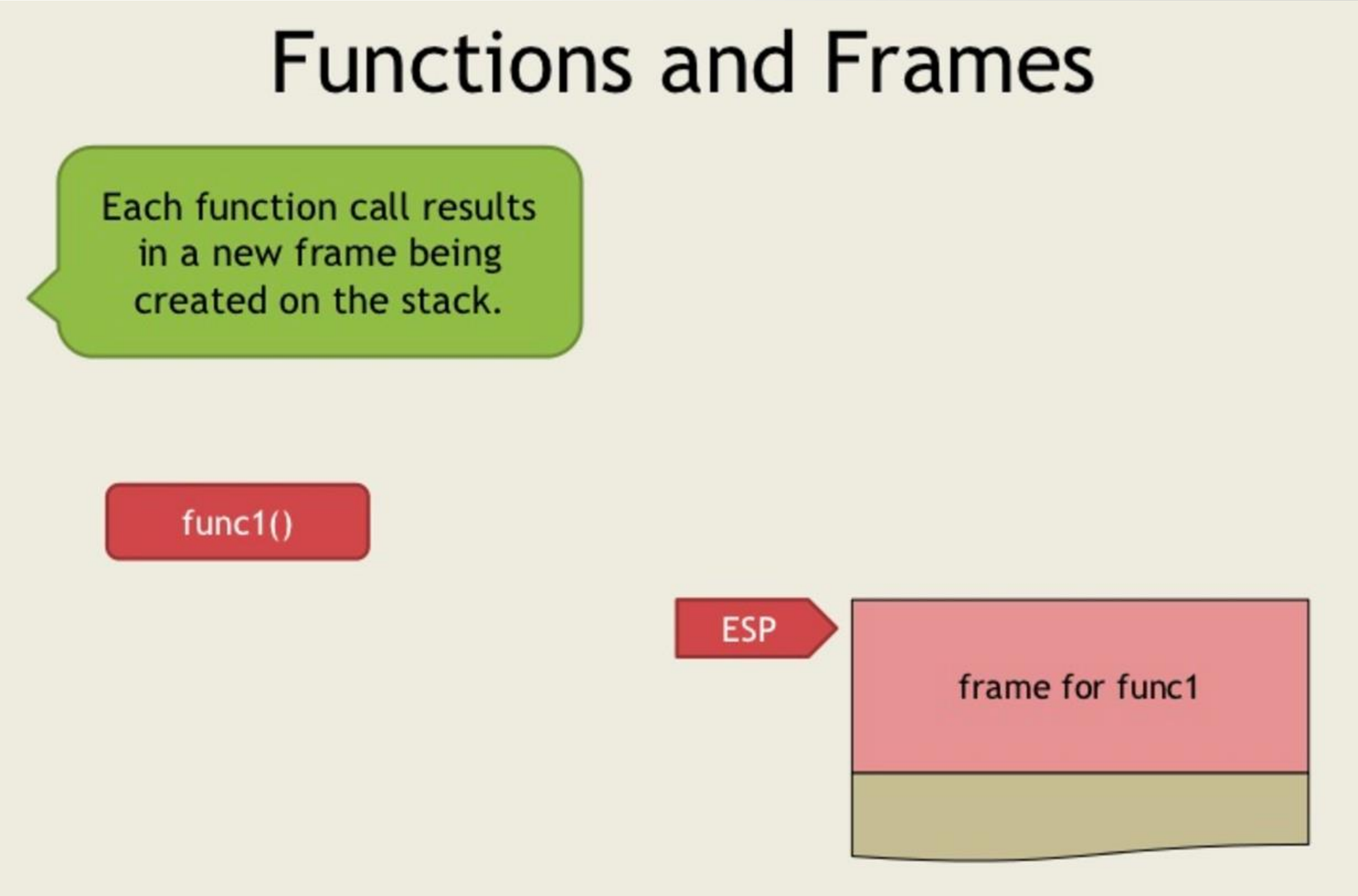
local variables of function (3)

return value of function (3)

Stack frame of function(3)

Local Variable

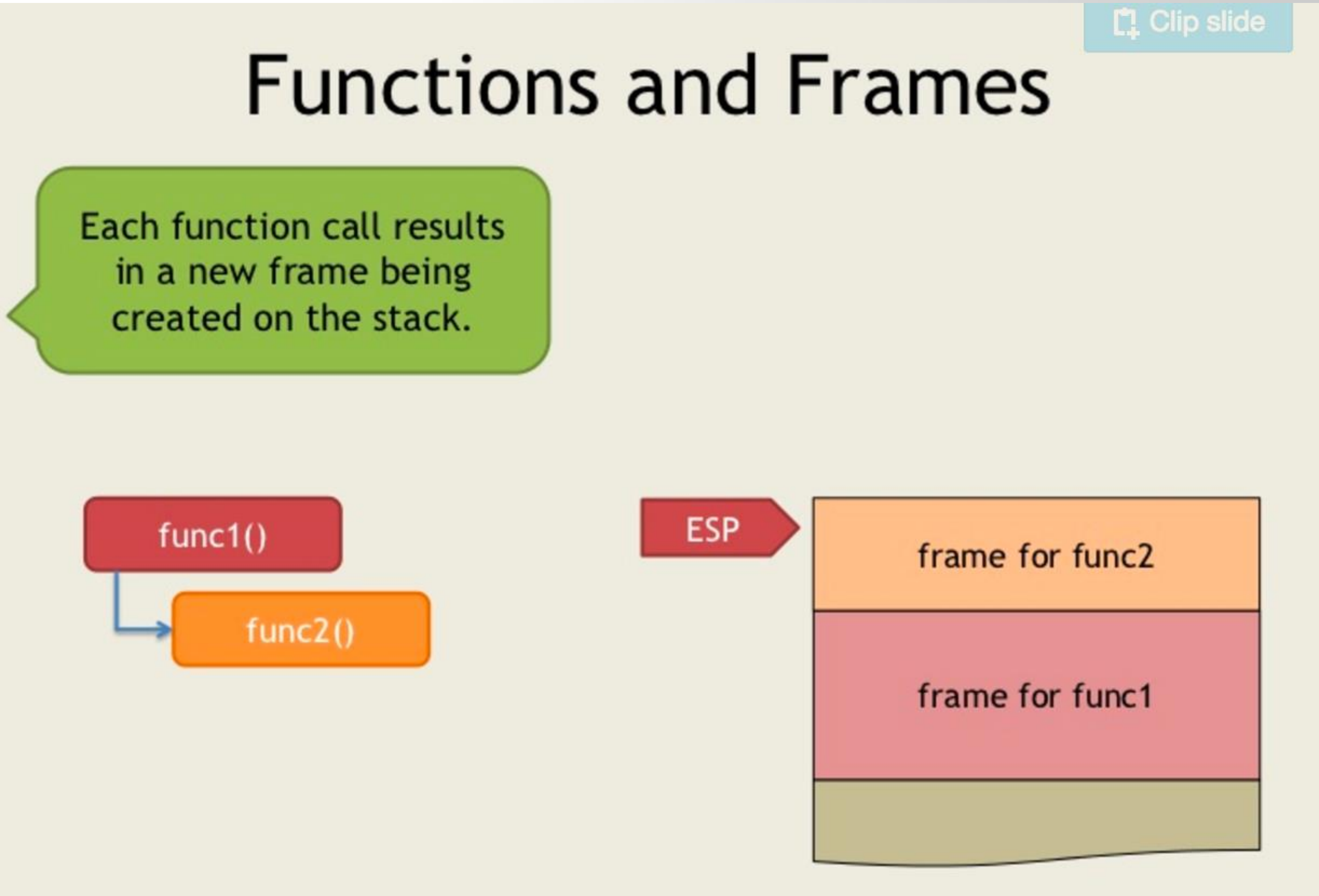
- Limited Register(s) → Store *Local Variable* in stack
  - Use *esp* and *ebp* to define a stack frame for current function
  - Use relative position of *esp* or *ebp* for retrieving and storing data
    - e.g. mov eax, [esp+124]
- Very easy to do recursive call



Functions and Frames

Each function call results in a new frame being created on the stack.

https://www.slideshare.net/saumilshah/how-functions-work-7776073



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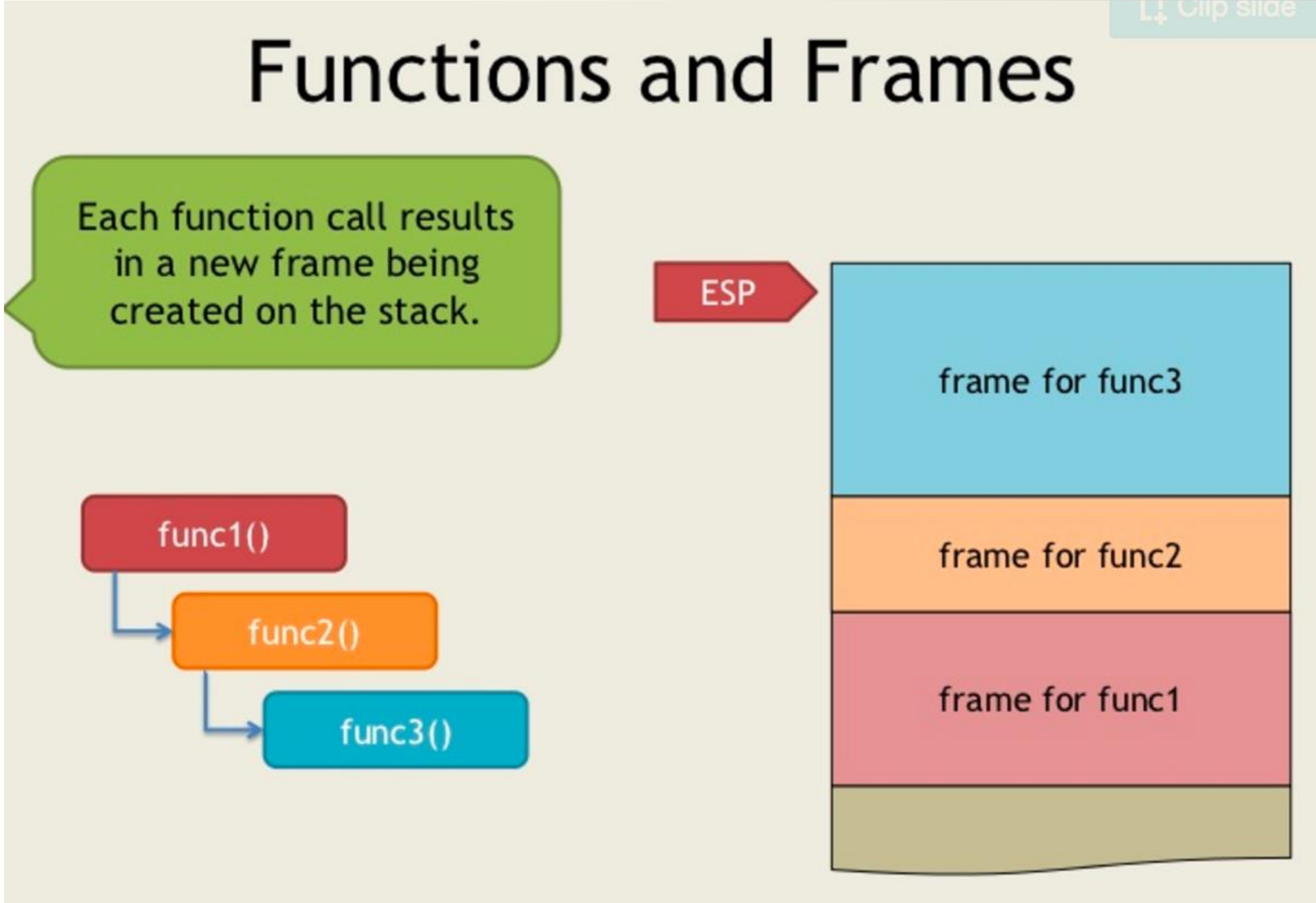


Functions and Frames

Each function call results in a new frame being created on the stack.

func1()

func2()

func3()

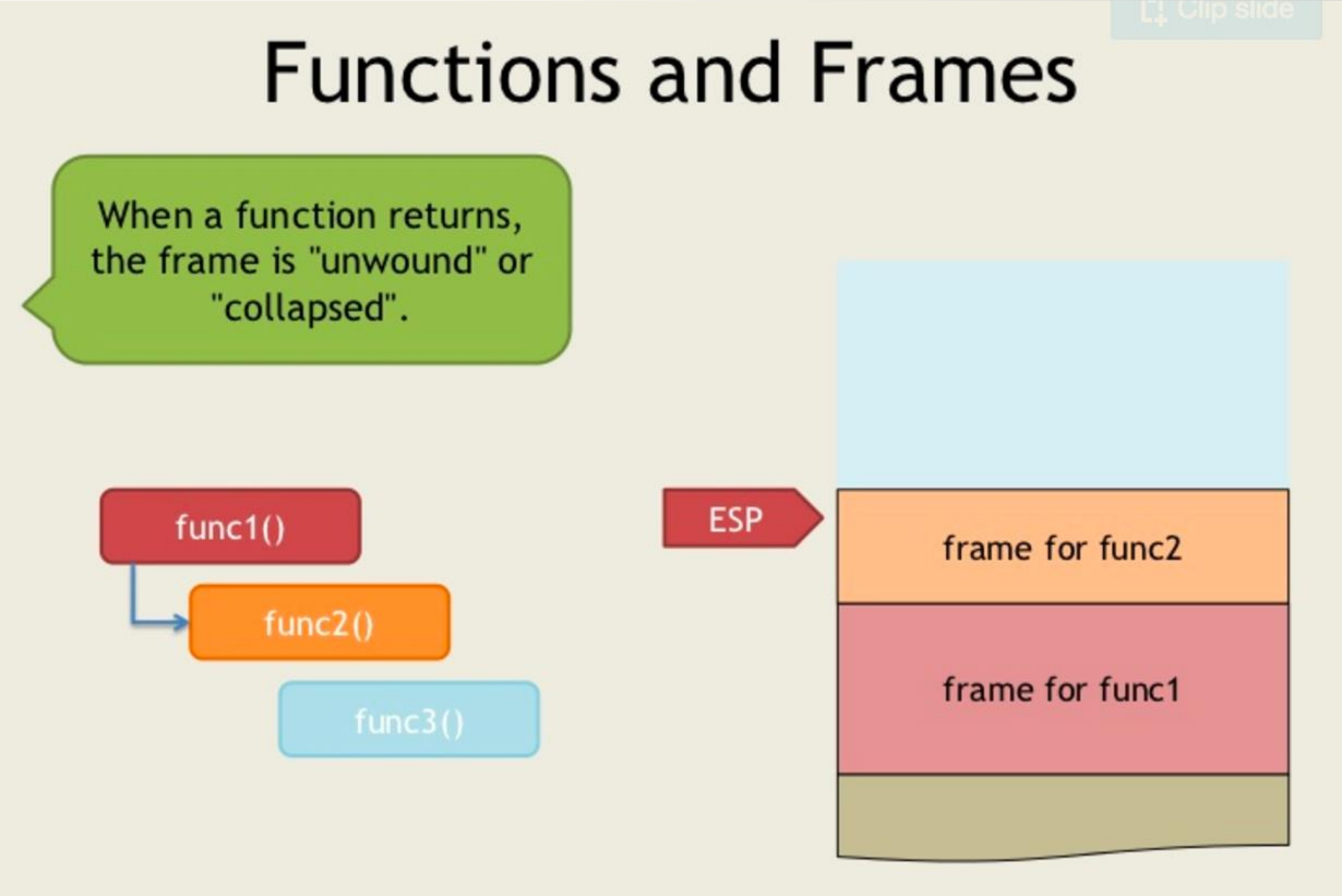
ESP

frame for func3

frame for func2

frame for func1

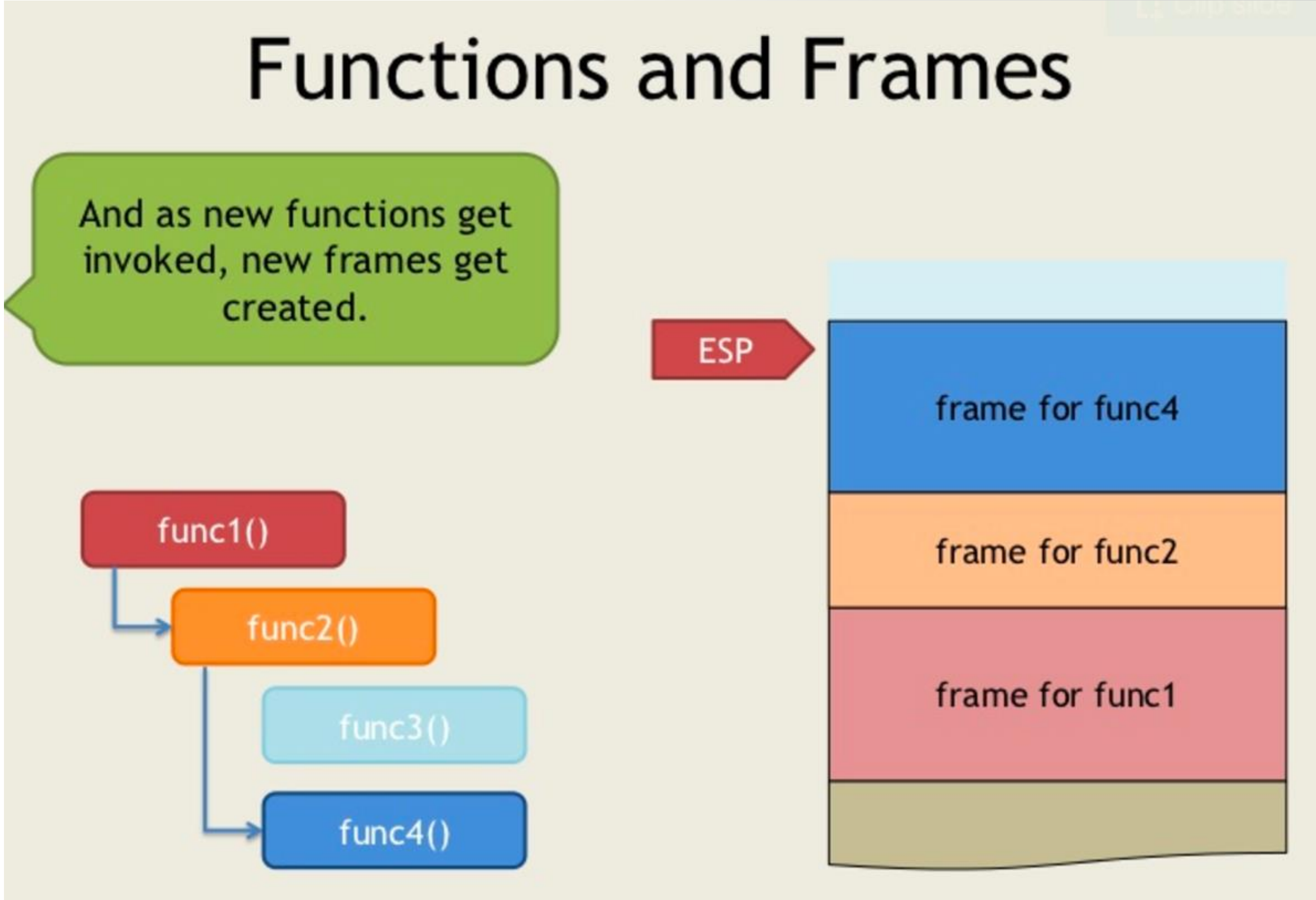
https://www.slideshare.net/saumilshah/how-functions-work-7776073



Functions and Frames

When a function returns, the frame is "unwound" or "collapsed".

https://www.slideshare.net/saumilshah/how-functions-work-7776073



Functions and Frames

And as new functions get invoked, new frames get created.

func1()

func2()

func3()

func4()

ESP

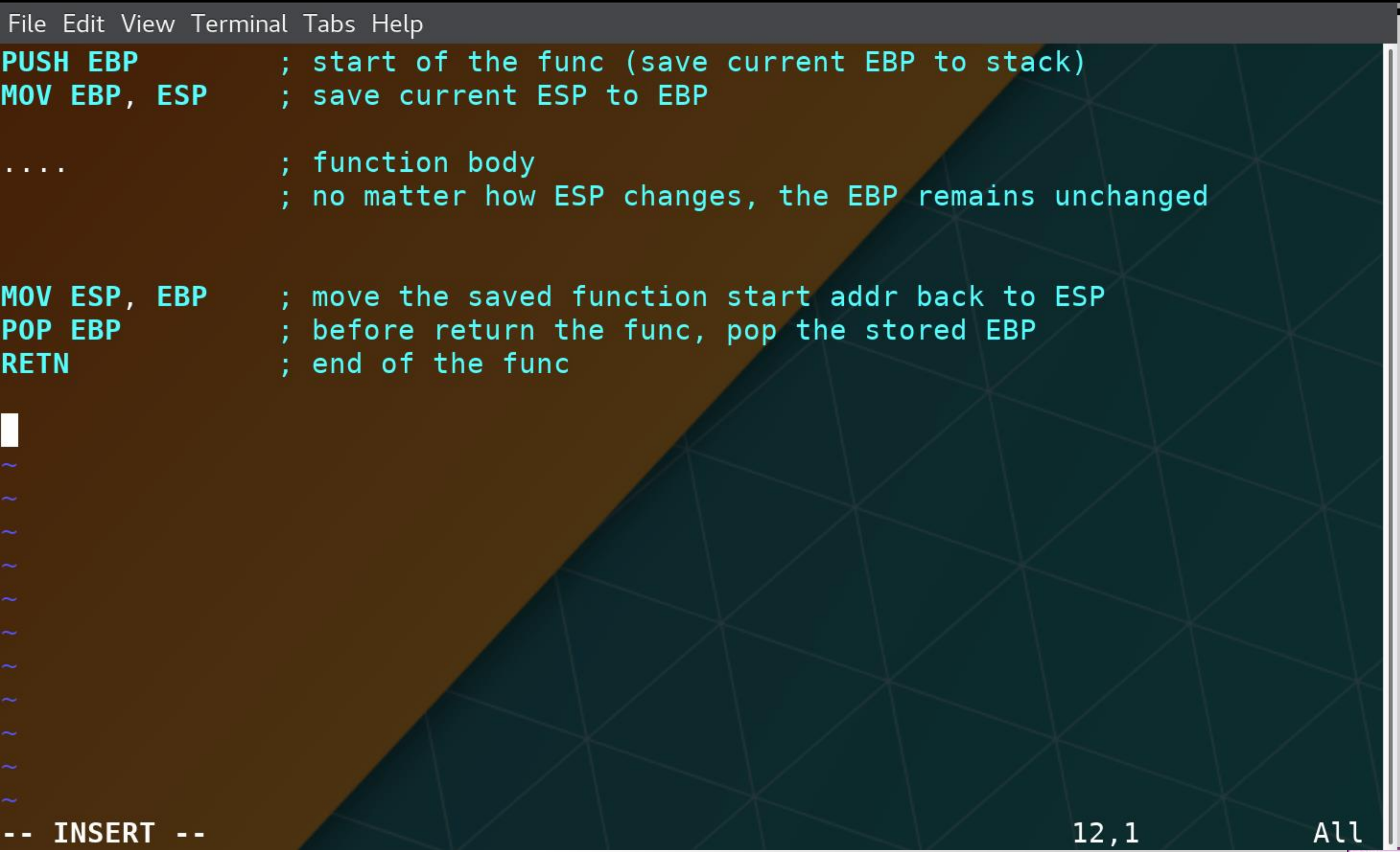
frame for func4

frame for func2

frame for func1

https://www.slideshare.net/saumilshah/how-functions-work-7776073

Stack Frame



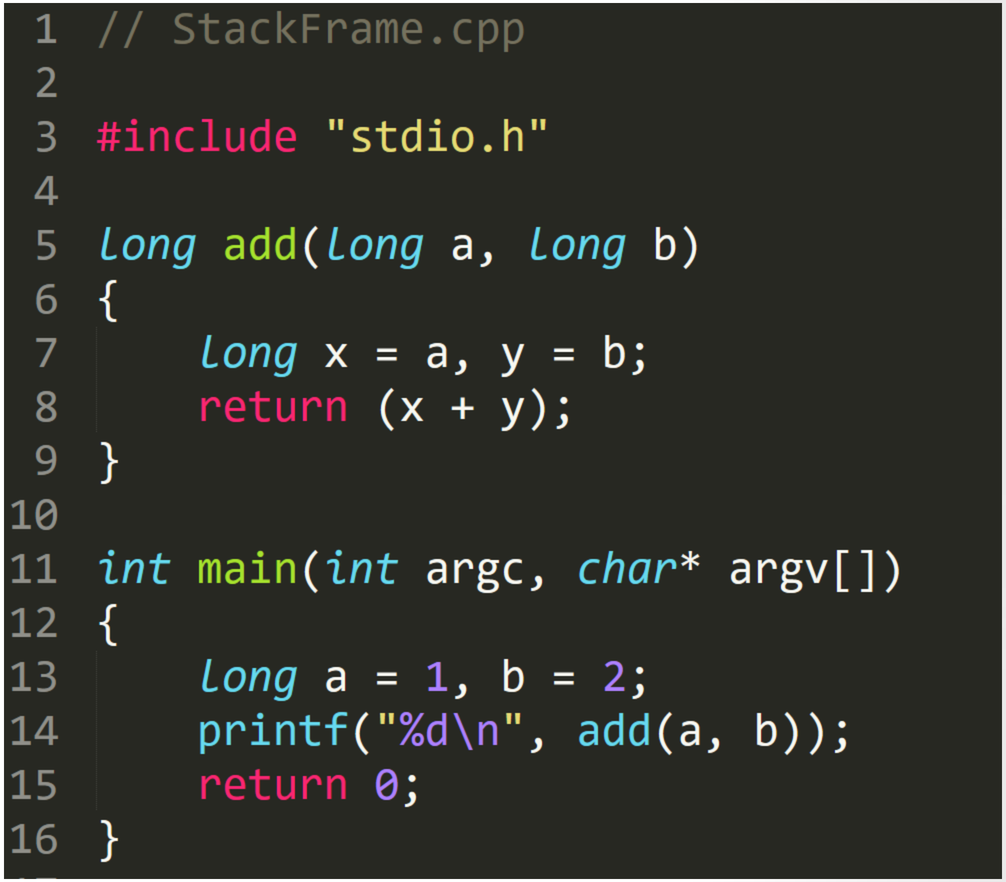
```
PUSH EBP          ; start of the func (save current EBP to stack)
MOV EBP, ESP      ; save current ESP to EBP

....              ; function body
                  ; no matter how ESP changes, the EBP remains unchanged


MOV ESP, EBP      ; move the saved function start addr back to ESP
POP EBP           ; before return the func, pop the stored EBP
RETN              ; end of the func


~
~
~
~
~
~
~
~
~
~
~
-- INSERT --                                                     12,1          All
```

StackFrame.exe



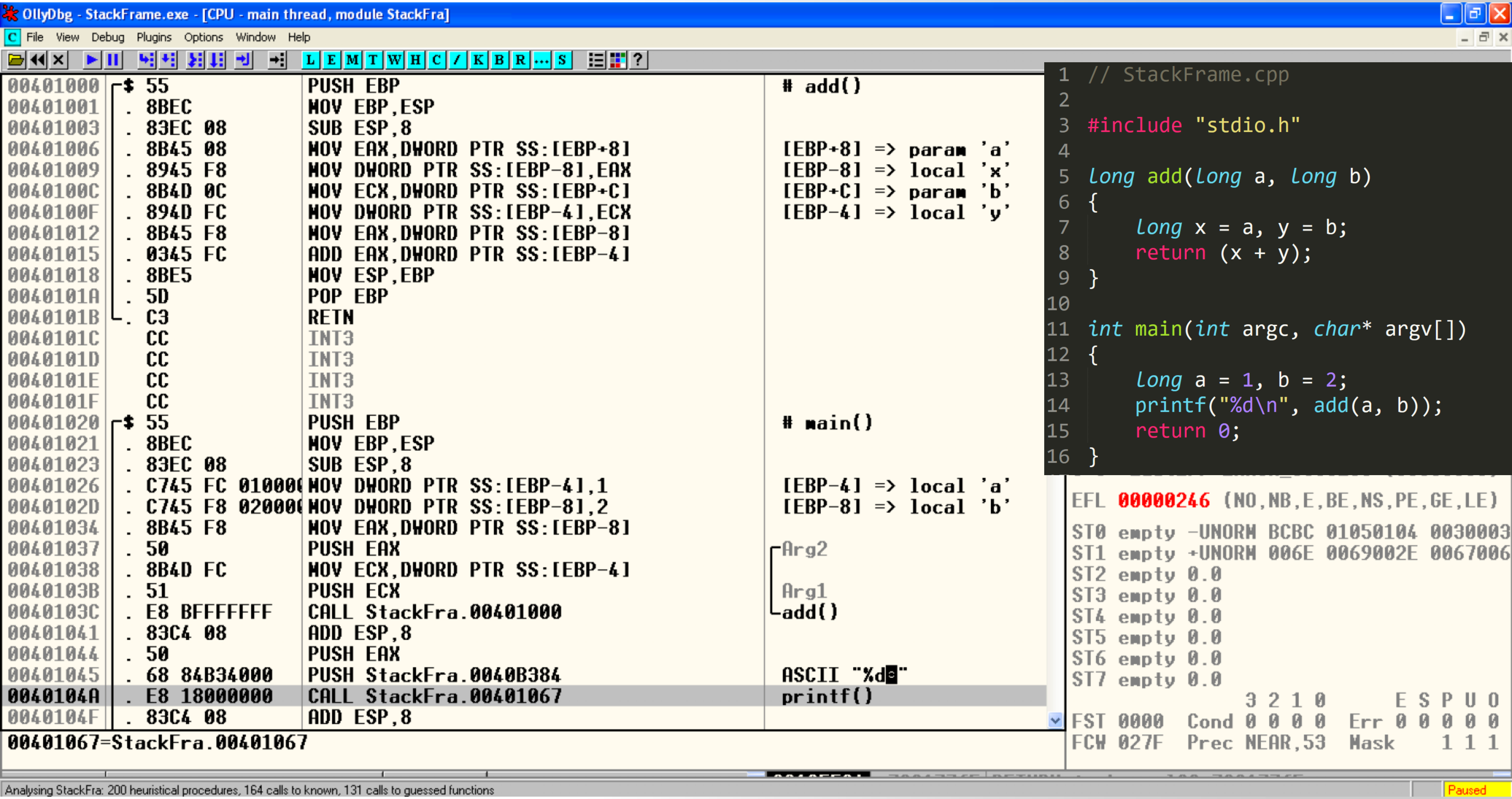
```
// StackFrame.cpp

#include "stdio.h"

long add(long a, long b)
{
	long x = a, y = b;
	return (x + y);
}

int main(int argc, char* argv[])
{
	long a = 1, b = 2;
	printf("%d\n", add(a, b));
	return 0;
}
```

StackFrame.exe



OllyDbg - StackFrame.exe - [CPU - main thread, module StackFra]
C File View Debug Plugins Options Window Help
L E M T W H C / K B R ... S

```
00401000 ┌$ 55            PUSH EBP                          # add()
00401001 .  8BEC          MOV EBP,ESP
00401003 .  83EC 08       SUB ESP,8
00401006 .  8B45 08       MOV EAX,DWORD PTR SS:[EBP+8]      [EBP+8] => param 'a'
00401009 .  8945 F8       MOV DWORD PTR SS:[EBP-8],EAX      [EBP-8] => local 'x'
0040100C .  8B4D 0C       MOV ECX,DWORD PTR SS:[EBP+C]      [EBP+C] => param 'b'
0040100F .  894D FC       MOV DWORD PTR SS:[EBP-4],ECX      [EBP-4] => local 'y'
00401012 .  8B45 F8       MOV EAX,DWORD PTR SS:[EBP-8]
00401015 .  0345 FC       ADD EAX,DWORD PTR SS:[EBP-4]
00401018 .  8BE5          MOV ESP,EBP
0040101A .  5D            POP EBP
0040101B └. C3            RETN
0040101C    CC            INT3
0040101D    CC            INT3
0040101E    CC            INT3
0040101F    CC            INT3
00401020 ┌$ 55            PUSH EBP                          # main()
00401021 .  8BEC          MOV EBP,ESP
00401023 .  83EC 08       SUB ESP,8
00401026 .  C745 FC 010000MOV DWORD PTR SS:[EBP-4],1        [EBP-4] => local 'a'
0040102D .  C745 F8 020000MOV DWORD PTR SS:[EBP-8],2        [EBP-8] => local 'b'
00401034 .  8B45 F8       MOV EAX,DWORD PTR SS:[EBP-8]
00401037 .  50            PUSH EAX                         ┌Arg2
00401038 .  8B4D FC       MOV ECX,DWORD PTR SS:[EBP-4]     │
0040103B .  51            PUSH ECX                         │Arg1
0040103C .  E8 BFFFFFFF   CALL StackFra.00401000           └add()
00401041 .  83C4 08       ADD ESP,8
00401044 .  50            PUSH EAX
00401045 .  68 84B34000   PUSH StackFra.0040B384            ASCII "%d"
0040104A .  E8 18000000   CALL StackFra.00401067            printf()
0040104F .  83C4 08       ADD ESP,8
00401067=StackFra.00401067
```

```
// StackFrame.cpp

#include "stdio.h"

long add(long a, long b)
{
    long x = a, y = b;
    return (x + y);
}

int main(int argc, char* argv[])
{
    long a = 1, b = 2;
    printf("%d\n", add(a, b));
    return 0;
}
```

```
EFL 00000246 (NO,NB,E,BE,NS,PE,GE,LE)

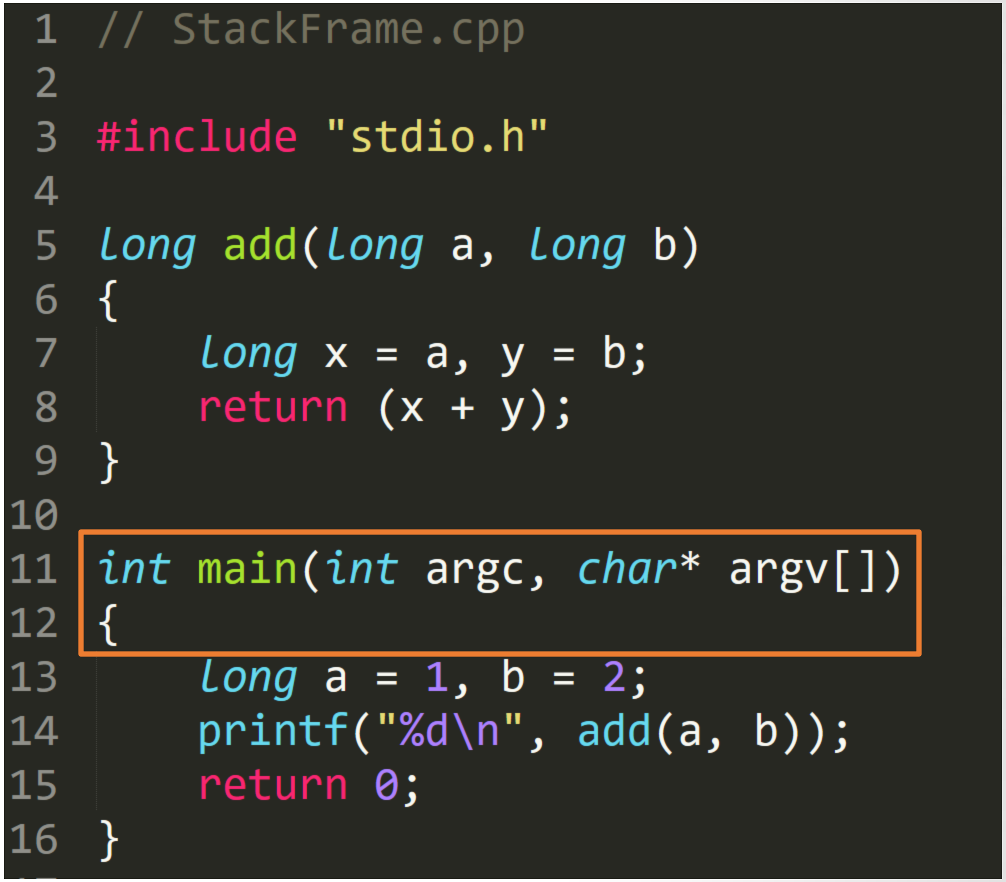
ST0 empty -UNORM BCBC 01050104 0030003
ST1 empty +UNORM 006E 0069002E 0067006
ST2 empty 0.0
ST3 empty 0.0
ST4 empty 0.0
ST5 empty 0.0
ST6 empty 0.0
ST7 empty 0.0
               3 2 1 0       E S P U O
FST 0000  Cond 0 0 0 0  Err 0 0 0 0 0
FCW 027F  Prec NEAR,53  Mask      1 1 1
```

Analysing StackFra: 200 heuristical procedures, 164 calls to known, 131 calls to guessed functions

Paused

EBP - n: Local vars
EBP + n: Parameters

StackFrame.exe



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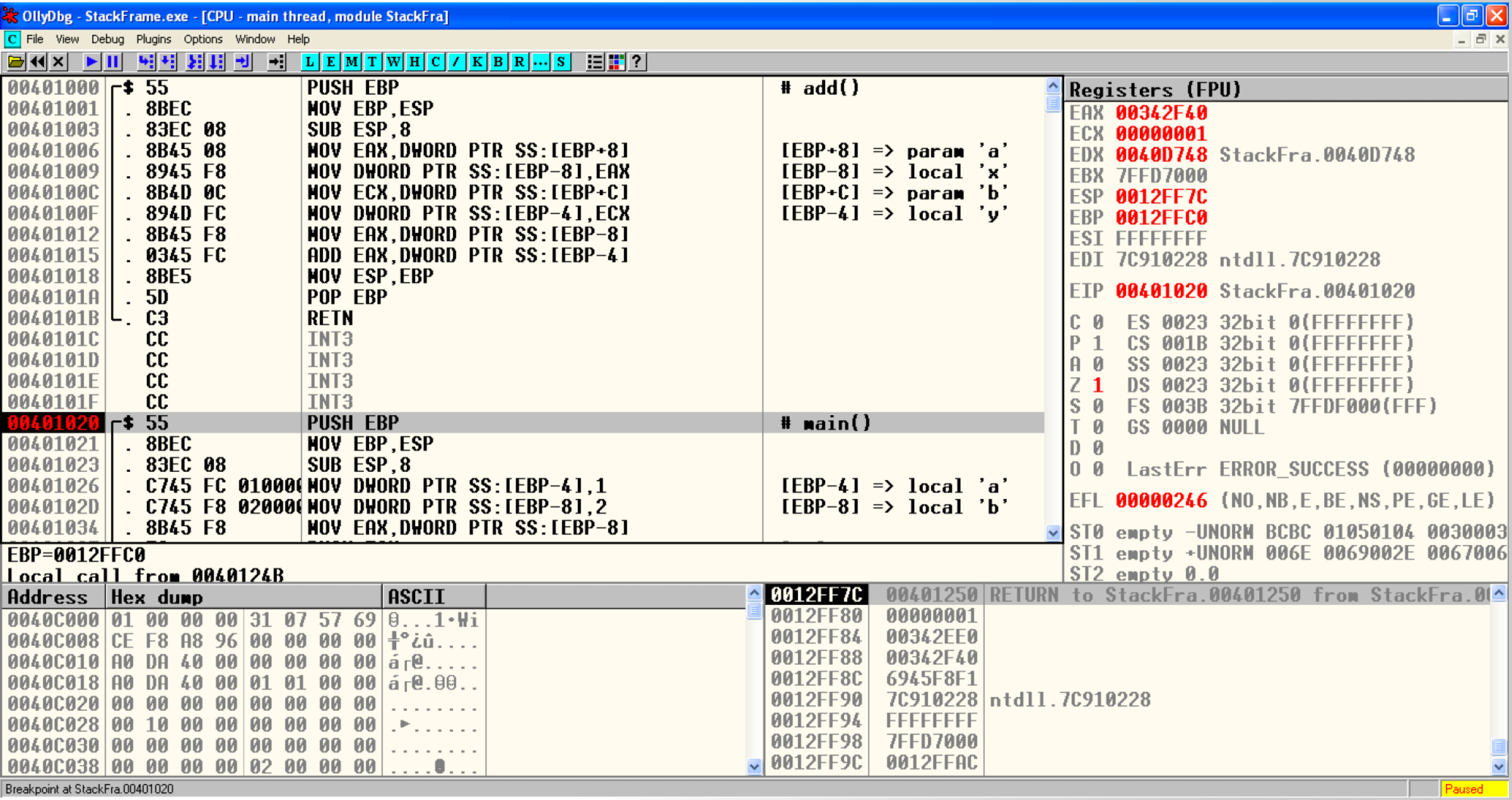
{
    long a = 1, b = 2;
    printf("%d\n", add(a, b));
    return 0;
}
```

StackFrame.exe



OllyDbg - StackFrame.exe - [CPU - main thread, module StackFra]
C File View Debug Plugins Options Window Help
L E M T W H C / K B R ... S ?

```
00401000 ┌$ 55            PUSH EBP                              # add()
00401001 │. 8BEC          MOV EBP,ESP
00401003 │. 83EC 08       SUB ESP,8
00401006 │. 8B45 08       MOV EAX,DWORD PTR SS:[EBP+8]          [EBP+8] => param 'a'
00401009 │. 8945 F8       MOV DWORD PTR SS:[EBP-8],EAX          [EBP-8] => local 'x'
0040100C │. 8B4D 0C       MOV ECX,DWORD PTR SS:[EBP+C]          [EBP+C] => param 'b'
0040100F │. 894D FC       MOV DWORD PTR SS:[EBP-4],ECX          [EBP-4] => local 'y'
00401012 │. 8B45 F8       MOV EAX,DWORD PTR SS:[EBP-8]
00401015 │. 0345 FC       ADD EAX,DWORD PTR SS:[EBP-4]
00401018 │. 8BE5          MOV ESP,EBP
0040101A │. 5D            POP EBP
0040101B └. C3            RETN
0040101C    CC            INT3
0040101D    CC            INT3
0040101E    CC            INT3
0040101F    CC            INT3
00401020 ┌$ 55            PUSH EBP                              # main()
00401021 │. 8BEC          MOV EBP,ESP
00401023 │. 83EC 08       SUB ESP,8
00401026 │. C745 FC 01000(MOV DWORD PTR SS:[EBP-4],1            [EBP-4] => local 'a'
0040102D │. C745 F8 02000(MOV DWORD PTR SS:[EBP-8],2            [EBP-8] => local 'b'
00401034 │. 8B45 F8       MOV EAX,DWORD PTR SS:[EBP-8]
```

```
EBP=0012FFC0
Local call from 0040124B
```

```
Registers (FPU)
EAX 00342F40
ECX 00000001
EDX 0040D748 StackFra.0040D748
EBX 7FFD7000
ESP 0012FF7C
EBP 0012FFC0
ESI FFFFFFFF
EDI 7C910228 ntdll.7C910228

EIP 00401020 StackFra.00401020

C 0  ES 0023 32bit 0(FFFFFFFF)
P 1  CS 001B 32bit 0(FFFFFFFF)
A 0  SS 0023 32bit 0(FFFFFFFF)
Z 1  DS 0023 32bit 0(FFFFFFFF)
S 0  FS 003B 32bit 7FFDF000(FFF)
T 0  GS 0000 NULL
D 0
O 0  LastErr ERROR_SUCCESS (00000000)

EFL 00000246 (NO,NB,E,BE,NS,PE,GE,LE)

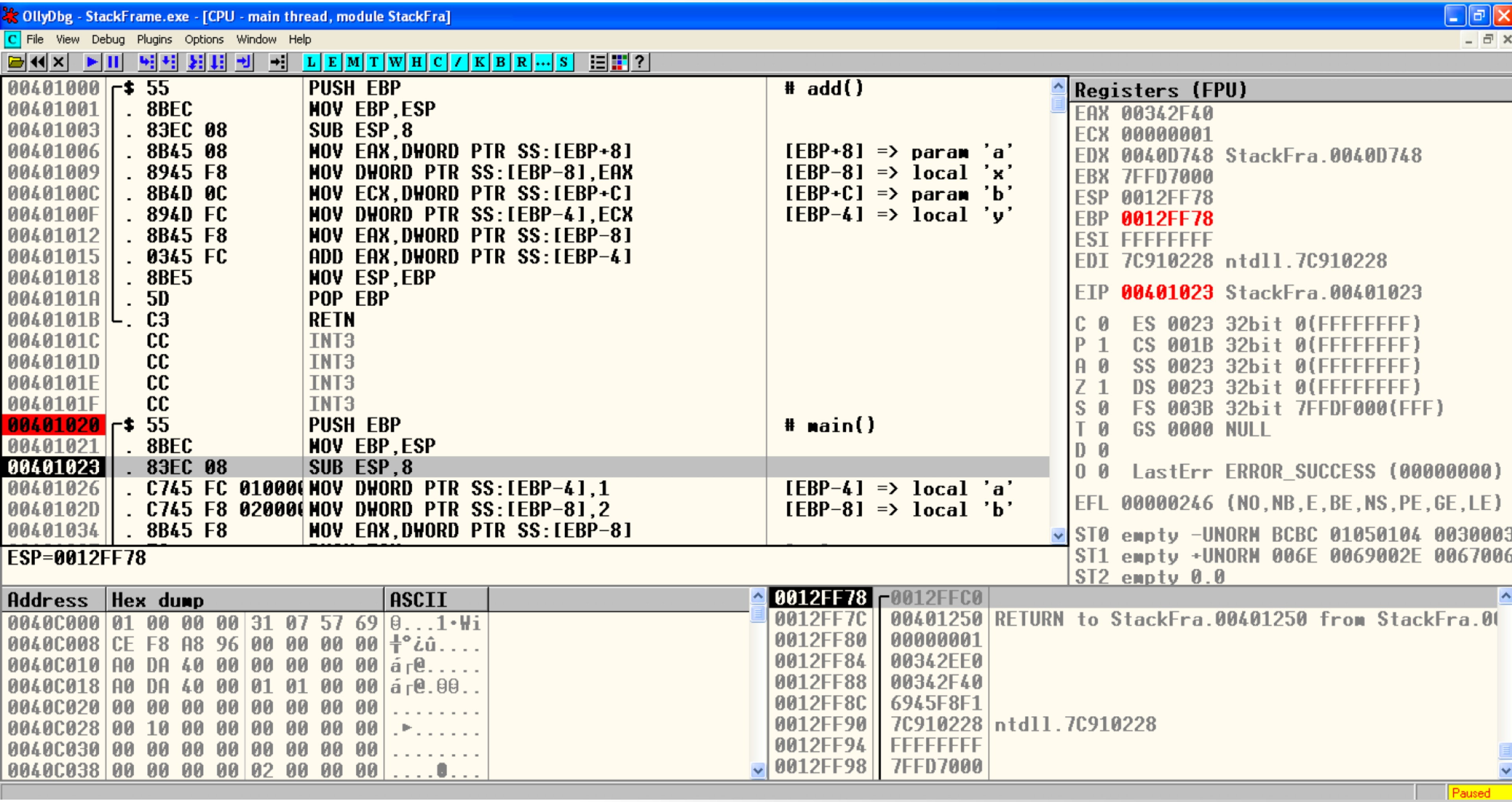
ST0 empty -UNORM BCBC 01050104 0030003
ST1 empty +UNORM 006E 0069002E 0067006
ST2 empty 0.0
```

```
Address  Hex dump                 ASCII
0040C000 01 00 00 00 31 07 57 69  ☺...1•Wi
0040C008 CE F8 A8 96 00 00 00 00  ╪°¿û....
0040C010 A0 DA 40 00 00 00 00 00  á┌@.....
0040C018 A0 DA 40 00 01 01 00 00  á┌@.☺☺..
0040C020 00 00 00 00 00 00 00 00  ........
0040C028 00 10 00 00 00 00 00 00  .►......
0040C030 00 00 00 00 00 00 00 00  ........
0040C038 00 00 00 00 02 00 00 00  ....☻...
```

```
0012FF7C  00401250  RETURN to StackFra.00401250 from StackFra.00
0012FF80  00000001
0012FF84  00342EE0
0012FF88  00342F40
0012FF8C  6945F8F1
0012FF90  7C910228  ntdll.7C910228
0012FF94  FFFFFFFF
0012FF98  7FFD7000
0012FF9C  0012FFAC
```

Breakpoint at StackFra.00401020

StackFrame.exe


OllyDbg - StackFrame.exe - [CPU - main thread, module StackFra]
File
View
Debug
Plugins
Options
Window
Help
L
E
M
T
W
H
C
/
K
B
R
...
S
?
Paused

```
00401000  ┌$ 55             PUSH EBP                          # add()
00401001  │. 8BEC           MOV EBP,ESP
00401003  │. 83EC 08        SUB ESP,8
00401006  │. 8B45 08        MOV EAX,DWORD PTR SS:[EBP+8]      [EBP+8] => param 'a'
00401009  │. 8945 F8        MOV DWORD PTR SS:[EBP-8],EAX      [EBP-8] => local 'x'
0040100C  │. 8B4D 0C        MOV ECX,DWORD PTR SS:[EBP+C]      [EBP+C] => param 'b'
0040100F  │. 894D FC        MOV DWORD PTR SS:[EBP-4],ECX      [EBP-4] => local 'y'
00401012  │. 8B45 F8        MOV EAX,DWORD PTR SS:[EBP-8]
00401015  │. 0345 FC        ADD EAX,DWORD PTR SS:[EBP-4]
00401018  │. 8BE5           MOV ESP,EBP
0040101A  │. 5D             POP EBP
0040101B  └. C3             RETN
0040101C     CC             INT3
0040101D     CC             INT3
0040101E     CC             INT3
0040101F     CC             INT3
00401020  ┌$ 55             PUSH EBP                          # main()
00401021  │. 8BEC           MOV EBP,ESP
00401023  │. 83EC 08        SUB ESP,8
00401026  │. C745 FC 010000(MOV DWORD PTR SS:[EBP-4],1        [EBP-4] => local 'a'
0040102D  │. C745 F8 020000(MOV DWORD PTR SS:[EBP-8],2        [EBP-8] => local 'b'
00401034  │. 8B45 F8        MOV EAX,DWORD PTR SS:[EBP-8]
ESP=0012FF78
```

```
Registers (FPU)
EAX 00342F40
ECX 00000001
EDX 0040D748 StackFra.0040D748
EBX 7FFD7000
ESP 0012FF78
EBP 0012FF78
ESI FFFFFFFF
EDI 7C910228 ntdll.7C910228

EIP 00401023 StackFra.00401023

C 0  ES 0023 32bit 0(FFFFFFFF)
P 1  CS 001B 32bit 0(FFFFFFFF)
A 0  SS 0023 32bit 0(FFFFFFFF)
Z 1  DS 0023 32bit 0(FFFFFFFF)
S 0  FS 003B 32bit 7FFDF000(FFF)
T 0  GS 0000 NULL
D 0
O 0  LastErr ERROR_SUCCESS (00000000)

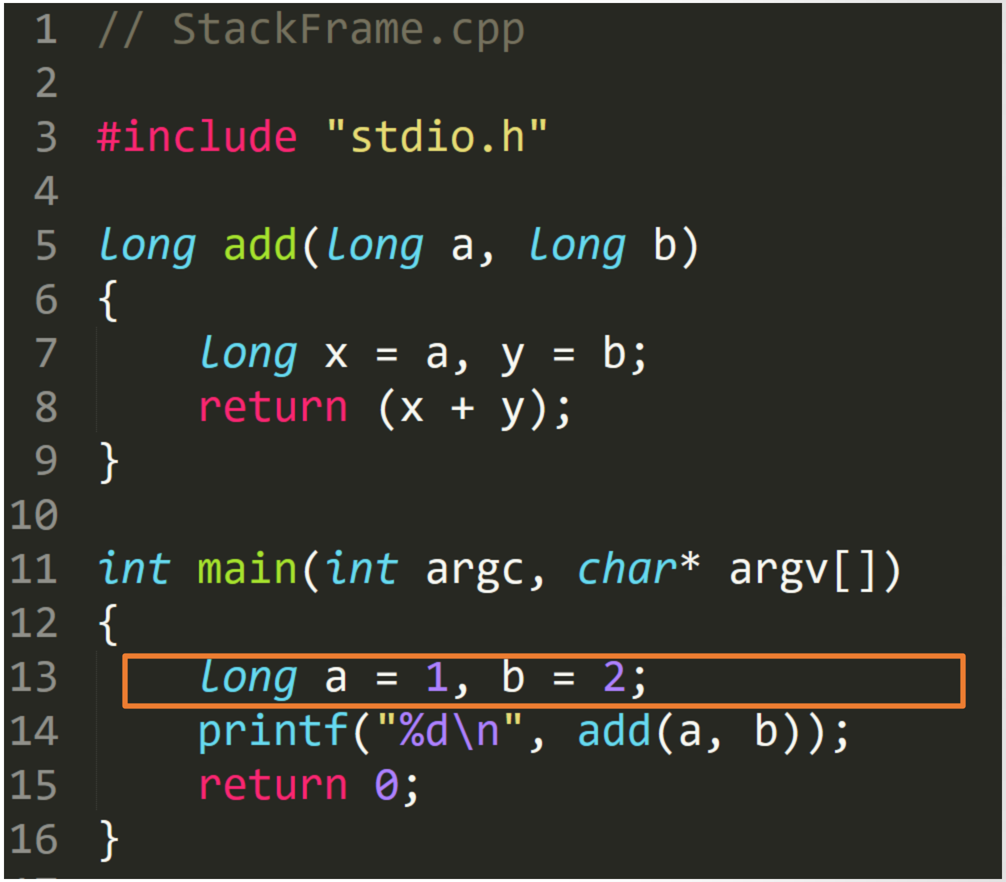
EFL 00000246 (NO,NB,E,BE,NS,PE,GE,LE)

ST0 empty -UNORM BCBC 01050104 0030003
ST1 empty +UNORM 006E 0069002E 0067006
ST2 empty 0.0
```

```
Address   Hex dump                  ASCII
0040C000  01 00 00 00 31 07 57 69  θ...1•Wi
0040C008  CE F8 A8 96 00 00 00 00  ╬°¿û....
0040C010  A0 DA 40 00 00 00 00 00  á┌@.....
0040C018  A0 DA 40 00 01 01 00 00  á┌@.θθ..
0040C020  00 00 00 00 00 00 00 00  ........
0040C028  00 10 00 00 00 00 00 00  .►......
0040C030  00 00 00 00 00 00 00 00  ........
0040C038  00 00 00 00 02 00 00 00  ....☻...
```

```
0012FF78  ┌0012FFC0
0012FF7C  │00401250  RETURN to StackFra.00401250 from StackFra.0(
0012FF80  │00000001
0012FF84  │00342EE0
0012FF88  │00342F40
0012FF8C  │6945F8F1
0012FF90  │7C910228  ntdll.7C910228
0012FF94  │FFFFFFFF
0012FF98  │7FFD7000
```

StackFrame.exe



```
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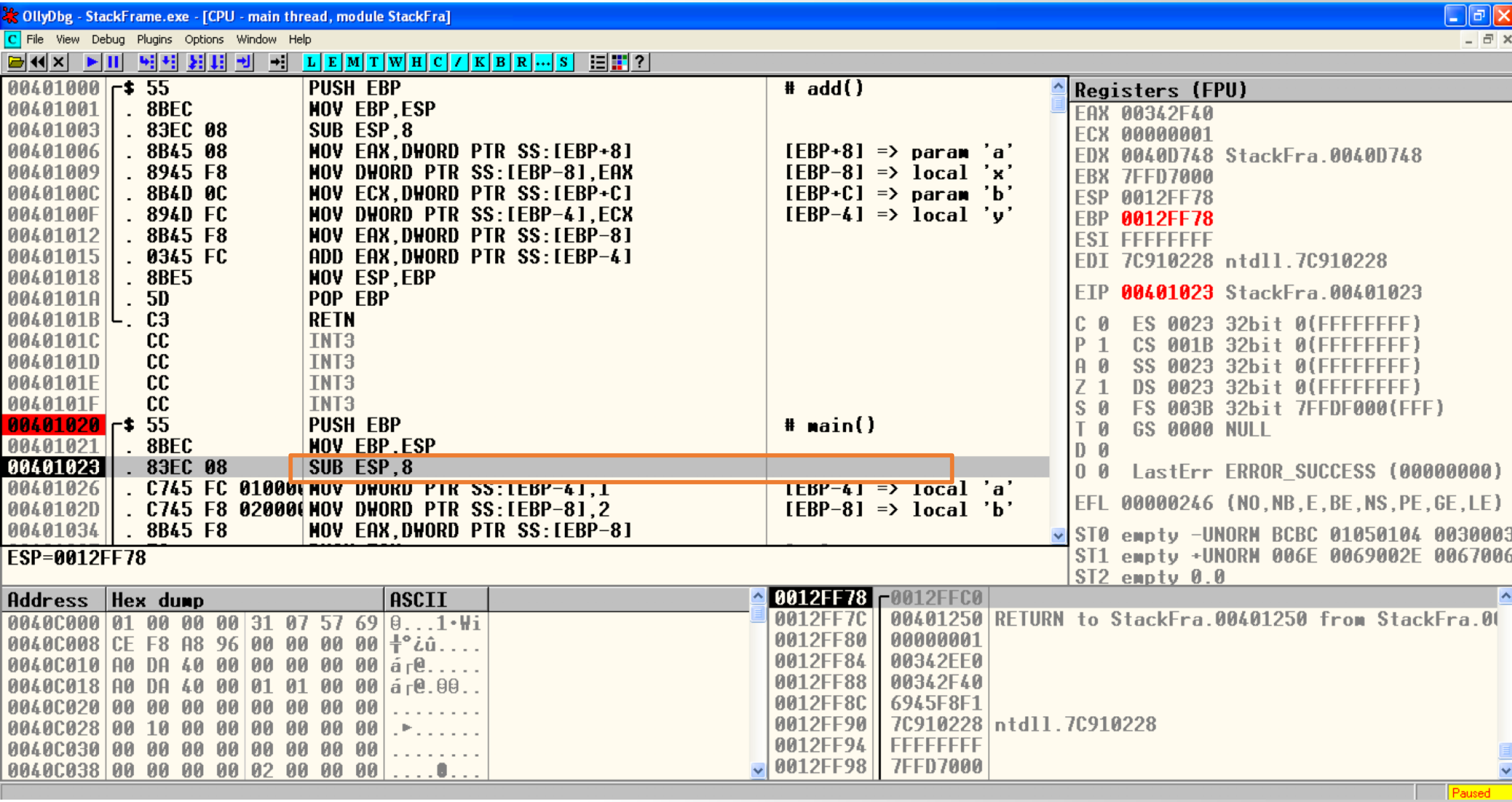
#include "stdio.h"

long add(long a, long b)
{
    long x = a, y = b;
    return (x + y);
}

int main(int argc, char* argv[])
{
    long a = 1, b = 2;
    printf("%d\n", add(a, b));
    return 0;
}
```

StackFrame.exe


OllyDbg - StackFrame.exe - [CPU - main thread, module StackFra]
C File View Debug Plugins Options Window Help
L E M T W H C / K B R ... S
Paused

```
00401000 ┌$ 55            PUSH EBP                              # add()
00401001 .  8BEC          MOV EBP,ESP
00401003 .  83EC 08       SUB ESP,8
00401006 .  8B45 08       MOV EAX,DWORD PTR SS:[EBP+8]          [EBP+8] => param 'a'
00401009 .  8945 F8       MOV DWORD PTR SS:[EBP-8],EAX          [EBP-8] => local 'x'
0040100C .  8B4D 0C       MOV ECX,DWORD PTR SS:[EBP+C]          [EBP+C] => param 'b'
0040100F .  894D FC       MOV DWORD PTR SS:[EBP-4],ECX          [EBP-4] => local 'y'
00401012 .  8B45 F8       MOV EAX,DWORD PTR SS:[EBP-8]
00401015 .  0345 FC       ADD EAX,DWORD PTR SS:[EBP-4]
00401018 .  8BE5          MOV ESP,EBP
0040101A .  5D            POP EBP
0040101B └. C3            RETN
0040101C    CC            INT3
0040101D    CC            INT3
0040101E    CC            INT3
0040101F    CC            INT3
00401020 ┌$ 55            PUSH EBP                              # main()
00401021 .  8BEC          MOV EBP,ESP
00401023 .  83EC 08       SUB ESP,8
00401026 .  C745 FC 01000(MOV DWORD PTR SS:[EBP-4],1            [EBP-4] => local 'a'
0040102D .  C745 F8 02000(MOV DWORD PTR SS:[EBP-8],2            [EBP-8] => local 'b'
00401034 .  8B45 F8       MOV EAX,DWORD PTR SS:[EBP-8]
ESP=0012FF78
```

```
Registers (FPU)
EAX 00342F40
ECX 00000001
EDX 0040D748 StackFra.0040D748
EBX 7FFD7000
ESP 0012FF78
EBP 0012FF78
ESI FFFFFFFF
EDI 7C910228 ntdll.7C910228

EIP 00401023 StackFra.00401023

C 0  ES 0023 32bit 0(FFFFFFFF)
P 1  CS 001B 32bit 0(FFFFFFFF)
A 0  SS 0023 32bit 0(FFFFFFFF)
Z 1  DS 0023 32bit 0(FFFFFFFF)
S 0  FS 003B 32bit 7FFDF000(FFF)
T 0  GS 0000 NULL
D 0
O 0  LastErr ERROR_SUCCESS (00000000)

EFL 00000246 (NO,NB,E,BE,NS,PE,GE,LE)

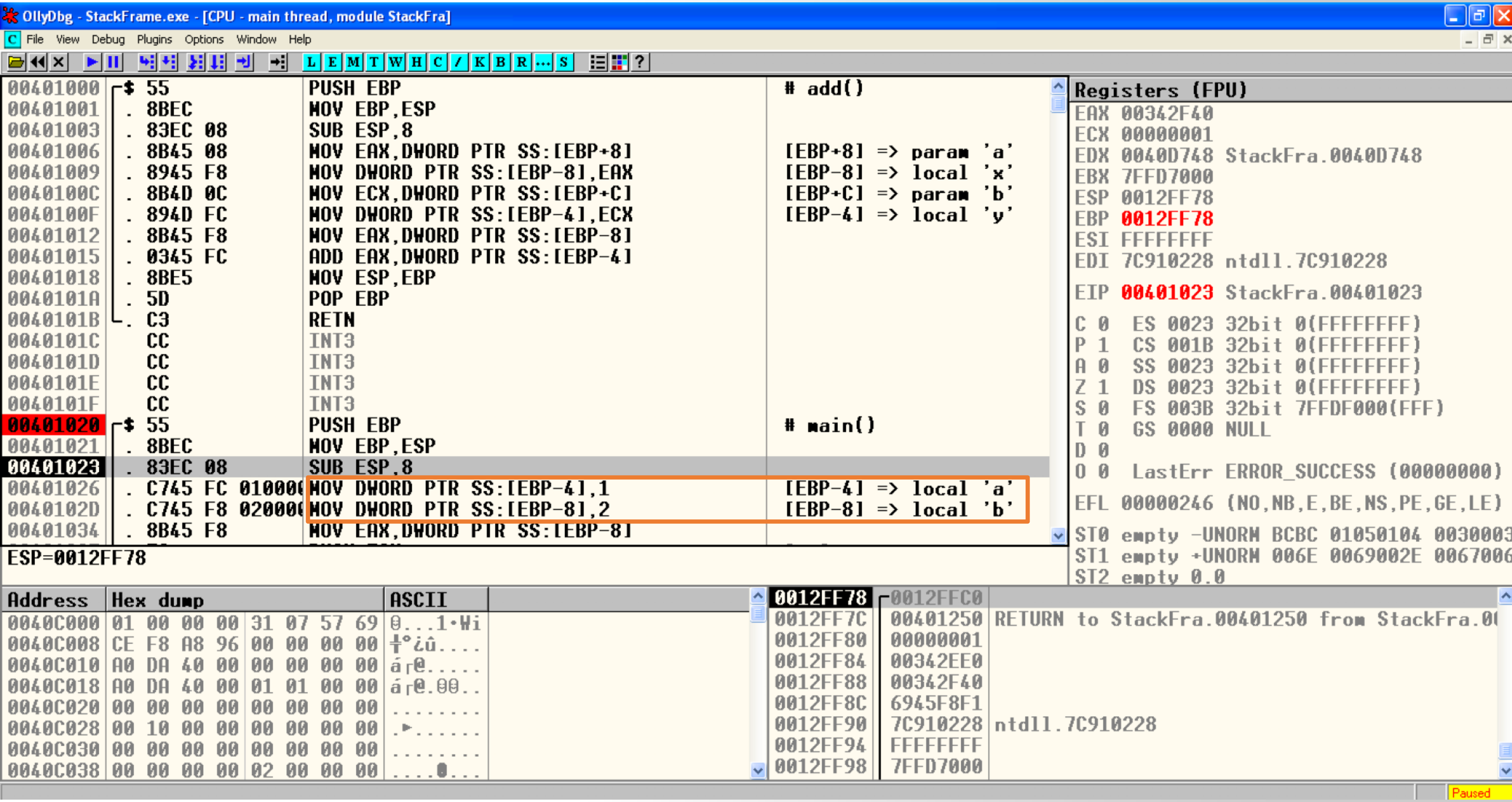
ST0 empty -UNORM BCBC 01050104 0030003
ST1 empty +UNORM 006E 0069002E 0067006
ST2 empty 0.0
```

```
Address   Hex dump                 ASCII
0040C000  01 00 00 00 31 07 57 69  θ...1•Wi
0040C008  CE F8 A8 96 00 00 00 00  ╬°¿û....
0040C010  A0 DA 40 00 00 00 00 00  á┌@.....
0040C018  A0 DA 40 00 01 01 00 00  á┌@.θθ..
0040C020  00 00 00 00 00 00 00 00  ........
0040C028  00 10 00 00 00 00 00 00  .►......
0040C030  00 00 00 00 00 00 00 00  ........
0040C038  00 00 00 00 02 00 00 00  ....☻...
```

```
0012FF78 ┌0012FFC0
0012FF7C  00401250  RETURN to StackFra.00401250 from StackFra.0(
0012FF80  00000001
0012FF84  00342EE0
0012FF88  00342F40
0012FF8C  6945F8F1
0012FF90  7C910228  ntdll.7C910228
0012FF94  FFFFFFFF
0012FF98  7FFD7000
```

Create space for ‘a’ and ‘b’ → long → 4 byte

StackFrame.exe


OllyDbg - StackFrame.exe - [CPU - main thread, module StackFra]
C File View Debug Plugins Options Window Help
L E M T W H C / K B R ... S
Paused

```
00401000 ┌$ 55            PUSH EBP                          # add()
00401001 .  8BEC          MOV EBP,ESP
00401003 .  83EC 08       SUB ESP,8
00401006 .  8B45 08       MOV EAX,DWORD PTR SS:[EBP+8]      [EBP+8] => param 'a'
00401009 .  8945 F8       MOV DWORD PTR SS:[EBP-8],EAX      [EBP-8] => local 'x'
0040100C .  8B4D 0C       MOV ECX,DWORD PTR SS:[EBP+C]      [EBP+C] => param 'b'
0040100F .  894D FC       MOV DWORD PTR SS:[EBP-4],ECX      [EBP-4] => local 'y'
00401012 .  8B45 F8       MOV EAX,DWORD PTR SS:[EBP-8]
00401015 .  0345 FC       ADD EAX,DWORD PTR SS:[EBP-4]
00401018 .  8BE5          MOV ESP,EBP
0040101A .  5D            POP EBP
0040101B └. C3            RETN
0040101C    CC            INT3
0040101D    CC            INT3
0040101E    CC            INT3
0040101F    CC            INT3
00401020 ┌$ 55            PUSH EBP                          # main()
00401021 .  8BEC          MOV EBP,ESP
00401023 .  83EC 08       SUB ESP,8
00401026 .  C745 FC 01000(MOV DWORD PTR SS:[EBP-4],1        [EBP-4] => local 'a'
0040102D .  C745 F8 02000(MOV DWORD PTR SS:[EBP-8],2        [EBP-8] => local 'b'
00401034 .  8B45 F8       MOV EAX,DWORD PTR SS:[EBP-8]
ESP=0012FF78
```

```
Registers (FPU)
EAX 00342F40
ECX 00000001
EDX 0040D748 StackFra.0040D748
EBX 7FFD7000
ESP 0012FF78
EBP 0012FF78
ESI FFFFFFFF
EDI 7C910228 ntdll.7C910228

EIP 00401023 StackFra.00401023

C 0  ES 0023 32bit 0(FFFFFFFF)
P 1  CS 001B 32bit 0(FFFFFFFF)
A 0  SS 0023 32bit 0(FFFFFFFF)
Z 1  DS 0023 32bit 0(FFFFFFFF)
S 0  FS 003B 32bit 7FFDF000(FFF)
T 0  GS 0000 NULL
D 0
O 0  LastErr ERROR_SUCCESS (00000000)

EFL 00000246 (NO,NB,E,BE,NS,PE,GE,LE)

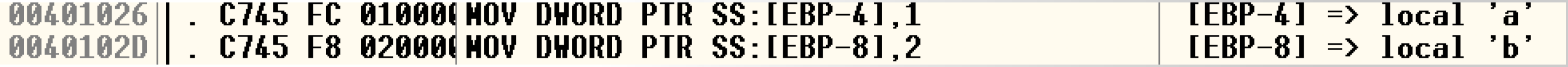
ST0 empty -UNORM BCBC 01050104 0030003
ST1 empty +UNORM 006E 0069002E 0067006
ST2 empty 0.0
```

```
Address  Hex dump                 ASCII
0040C000 01 00 00 00 31 07 57 69  ☺...1•Wi
0040C008 CE F8 A8 96 00 00 00 00  ╬°¿û....
0040C010 A0 DA 40 00 00 00 00 00  á┌@.....
0040C018 A0 DA 40 00 01 01 00 00  á┌@.☺☺..
0040C020 00 00 00 00 00 00 00 00  ........
0040C028 00 10 00 00 00 00 00 00  .►......
0040C030 00 00 00 00 00 00 00 00  ........
0040C038 00 00 00 00 02 00 00 00  ....☻...
```

```
0012FF78 ┌0012FFC0
0012FF7C  00401250 RETURN to StackFra.00401250 from StackFra.0(
0012FF80  00000001
0012FF84  00342EE0
0012FF88  00342F40
0012FF8C  6945F8F1
0012FF90  7C910228 ntdll.7C910228
0012FF94  FFFFFFFF
0012FF98  7FFD7000
```

Create space for ‘a’ and ‘b’ → long → 4 byte

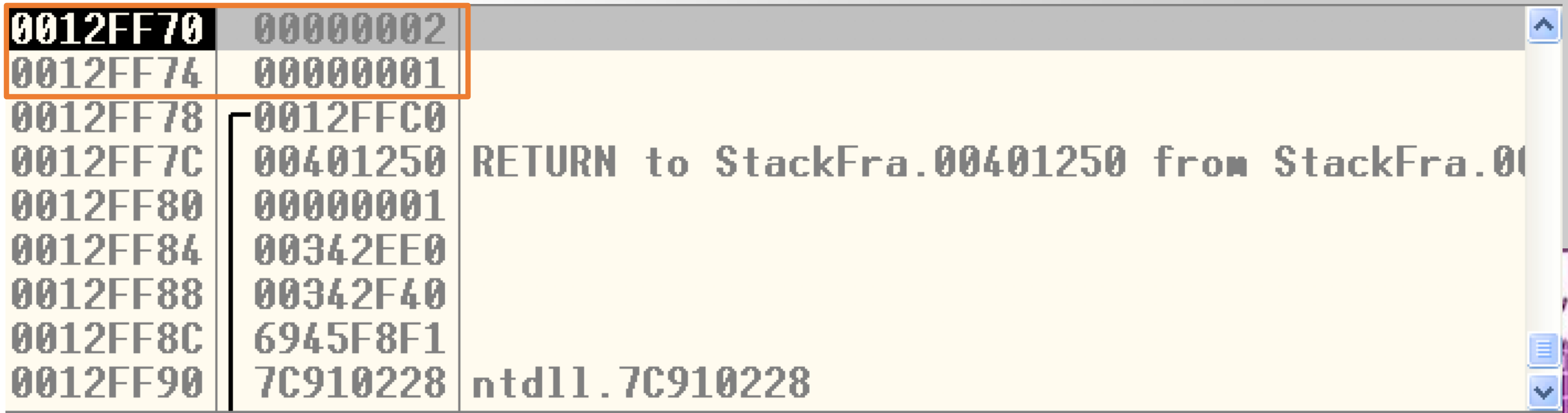
StackFrame.exe



```
00401026 |. C745 FC 010000( MOV DWORD PTR SS:[EBP-4],1    [EBP-4] => local 'a'
0040102D |. C745 F8 020000( MOV DWORD PTR SS:[EBP-8],2    [EBP-8] => local 'b'
```

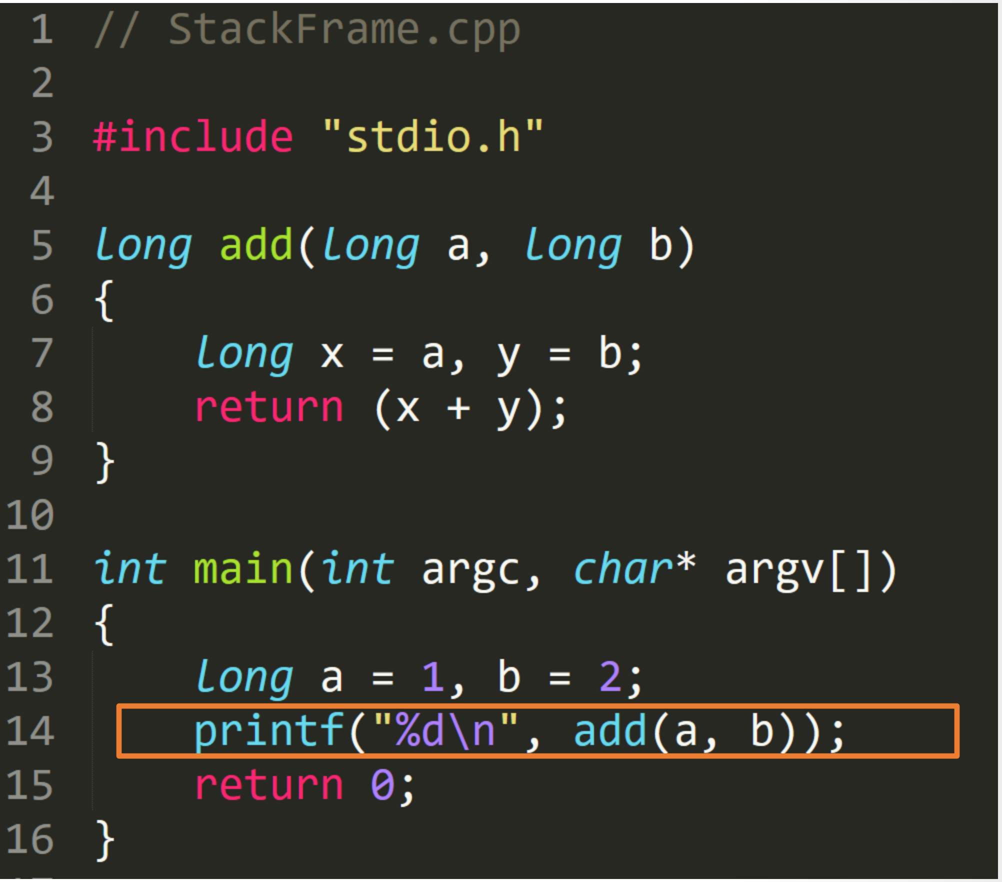
Assembly	C	Type Conversion
DWORD PTR SS:[EBP-4]	*(DWORD*)(EBP-4)	DWORD (4 byte)
WORD PTR SS:[EBP-4]	*(WORD*)(EBP-4)	WORD (2 byte)
BYTE PTR SS:[EBP-4]	*(BYTE*)(EBP-4)	1 byte

4 Byte memory space at address [EBP-4]



```
0012FF70   00000002
0012FF74   00000001
0012FF78  ┌0012FFC0
0012FF7C  │00401250  RETURN to StackFra.00401250 from StackFra.0(
0012FF80  │00000001
0012FF84  │00342EE0
0012FF88  │00342F40
0012FF8C  │6945F8F1
0012FF90  │7C910228  ntdll.7C910228
```

StackFrame.exe

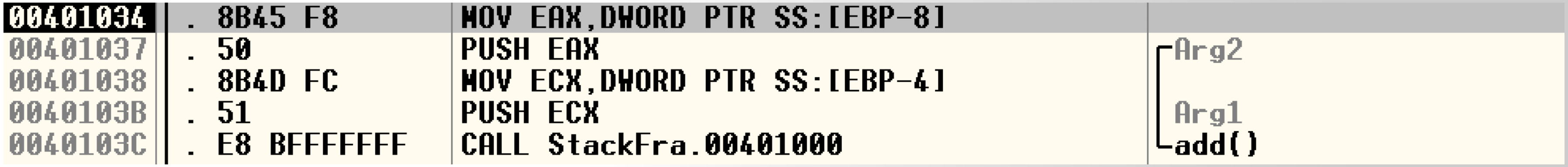


```
// StackFrame.cpp

#include "stdio.h"

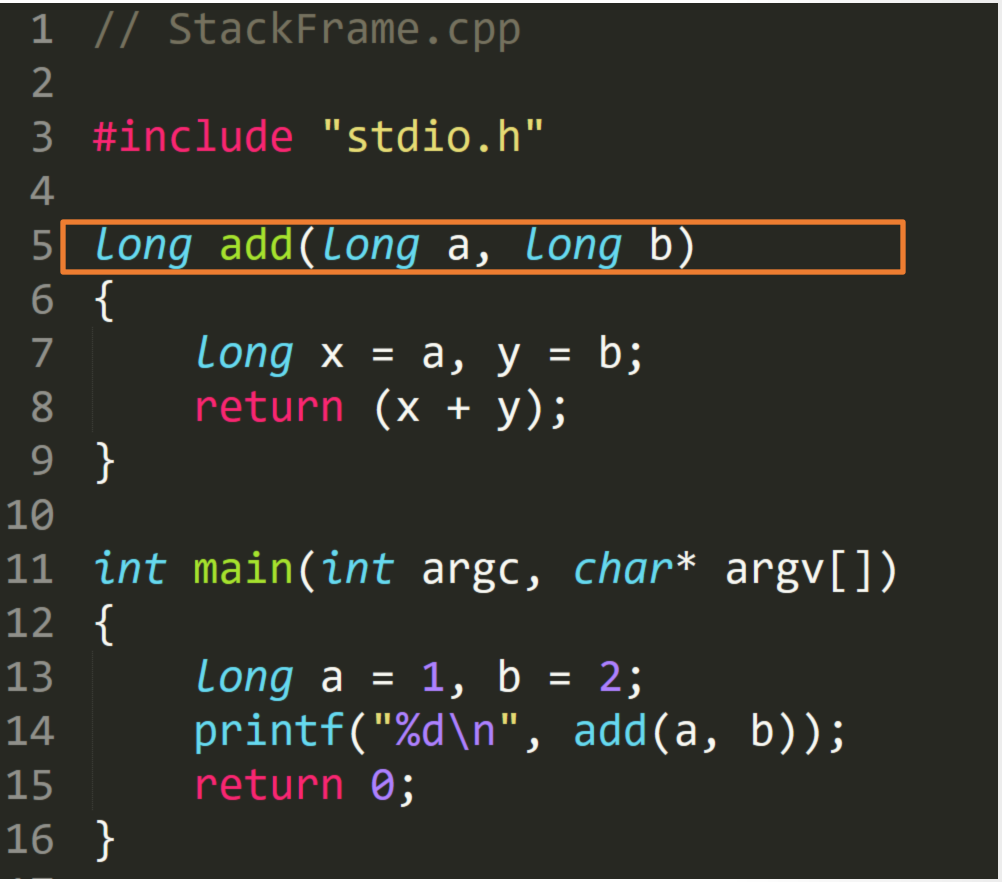
long add(long a, long b)
{
    long x = a, y = b;
    return (x + y);
}

int main(int argc, char* argv[])
{
    long a = 1, b = 2;
    printf("%d\n", add(a, b));
    return 0;
}
```



```
00401034  .  8B45 F8        MOV EAX,DWORD PTR SS:[EBP-8]
00401037  .  50             PUSH EAX                          ┌Arg2
00401038  .  8B4D FC        MOV ECX,DWORD PTR SS:[EBP-4]      │
0040103B  .  51             PUSH ECX                          │Arg1
0040103C  .  E8 BFFFFFFF    CALL StackFra.00401000            └add()
```

StackFrame.exe

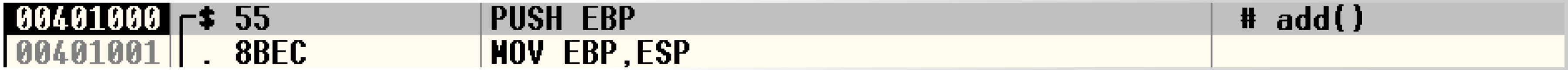


```
// StackFrame.cpp

#include "stdio.h"

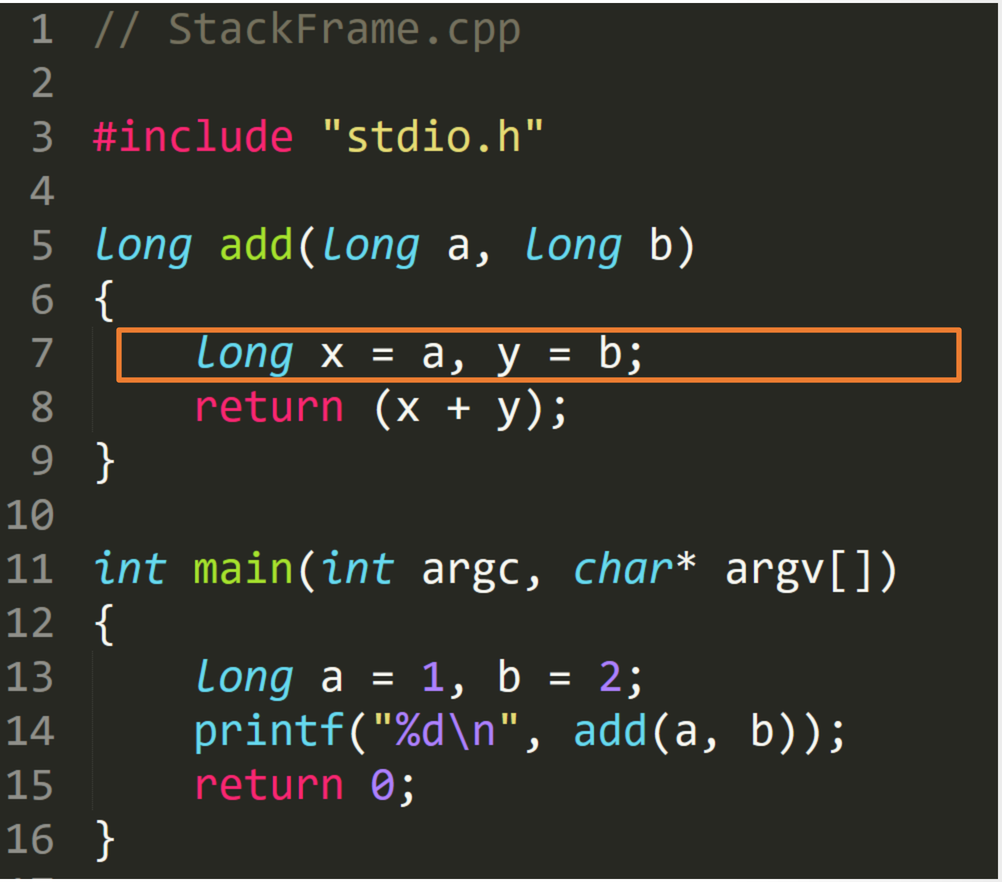
long add(long a, long b)
{
    long x = a, y = b;
    return (x + y);
}

int main(int argc, char* argv[])
{
    long a = 1, b = 2;
    printf("%d\n", add(a, b));
    return 0;
}
```

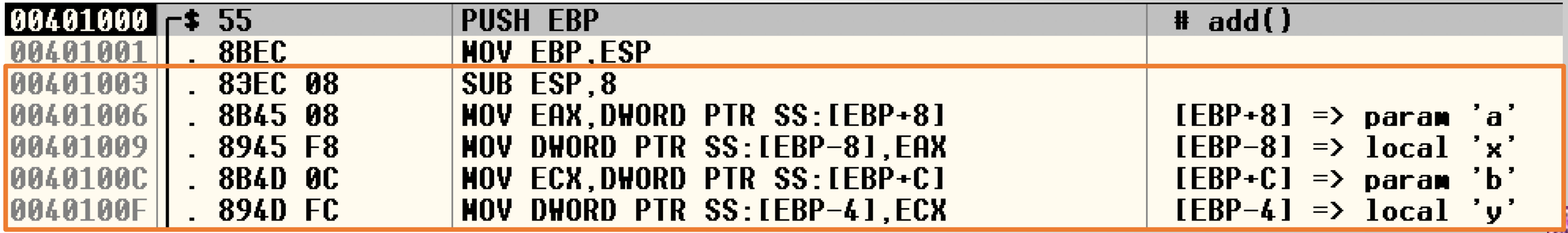


```
00401000  ┌$ 55      PUSH EBP           # add()
00401001  │. 8BEC    MOV EBP,ESP
```

StackFrame.exe

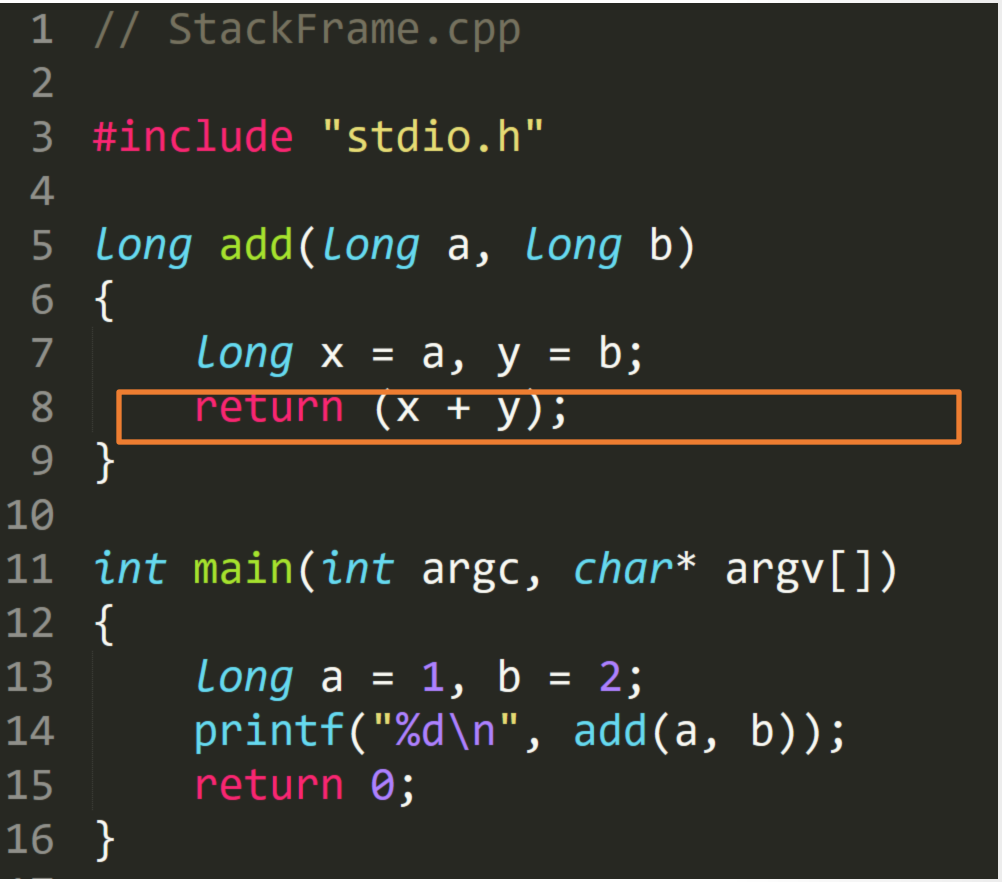


```cpp
// StackFrame.cpp

#include "stdio.h"

long add(long a, long b)
{
    long x = a, y = b;
    return (x + y);
}

int main(int argc, char* argv[])
{
    long a = 1, b = 2;
    printf("%d\n", add(a, b));
    return 0;
}
```



```
00401000  ┌$ 55         PUSH EBP                              # add()
00401001  │. 8BEC       MOV EBP,ESP
00401003  │. 83EC 08    SUB ESP,8
00401006  │. 8B45 08    MOV EAX,DWORD PTR SS:[EBP+8]          [EBP+8] => param 'a'
00401009  │. 8945 F8    MOV DWORD PTR SS:[EBP-8],EAX          [EBP-8] => local 'x'
0040100C  │. 8B4D 0C    MOV ECX,DWORD PTR SS:[EBP+C]          [EBP+C] => param 'b'
0040100F  │. 894D FC    MOV DWORD PTR SS:[EBP-4],ECX          [EBP-4] => local 'y'
```

StackFrame.exe



```
// StackFrame.cpp

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{
    long x = a, y = b;
    return (x + y);
}

int main(int argc, char* argv[])
{
    long a = 1, b = 2;
    printf("%d\n", add(a, b));
    return 0;
}
```
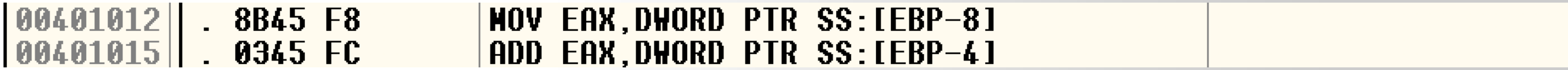
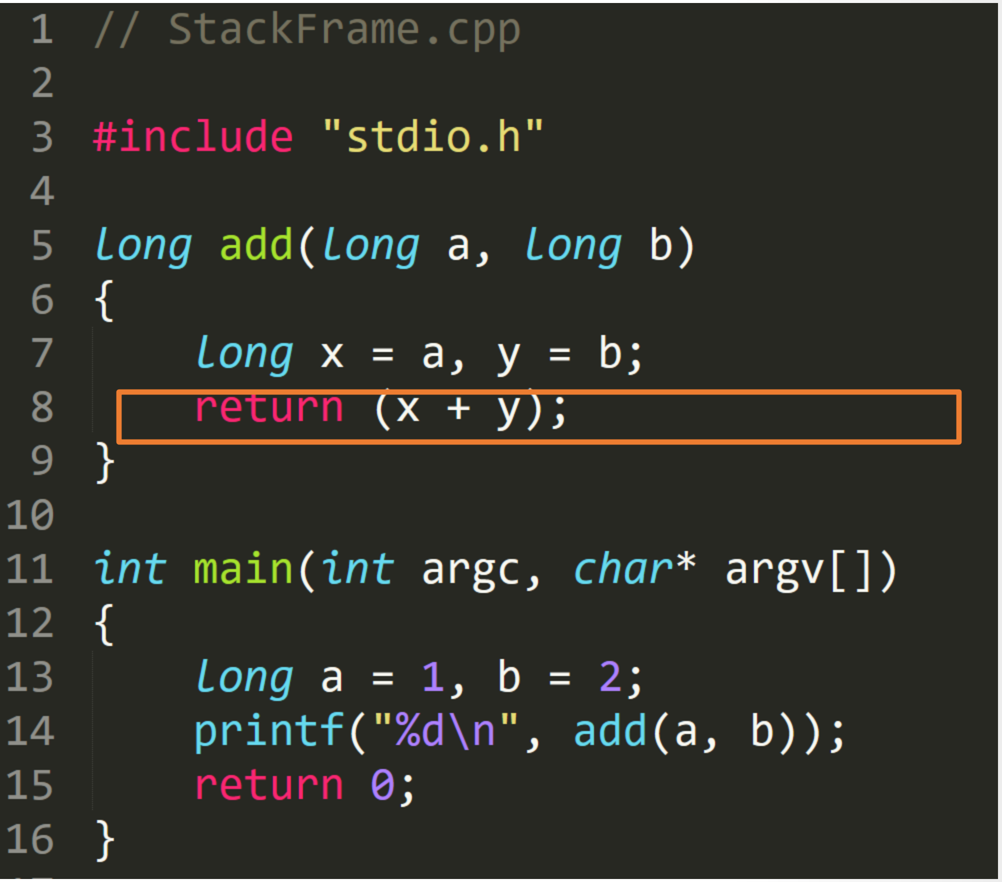



```
00401012  .  8B45 F8       MOV EAX,DWORD PTR SS:[EBP-8]
00401015  .  0345 FC       ADD EAX,DWORD PTR SS:[EBP-4]
```

StackFrame.exe



```
// StackFrame.cpp

#include "stdio.h"

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{
    long x = a, y = b;
    return (x + y);
}

int main(int argc, char* argv[])
{
    long a = 1, b = 2;
    printf("%d\n", add(a, b));
    return 0;
}
```
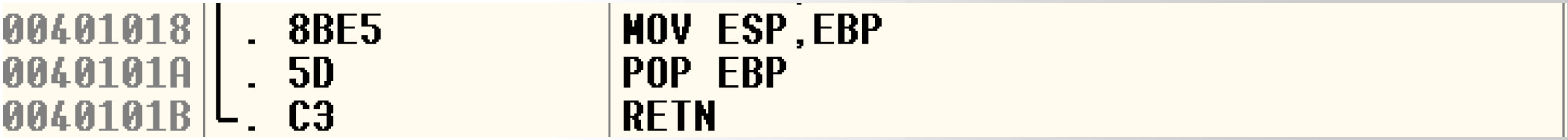
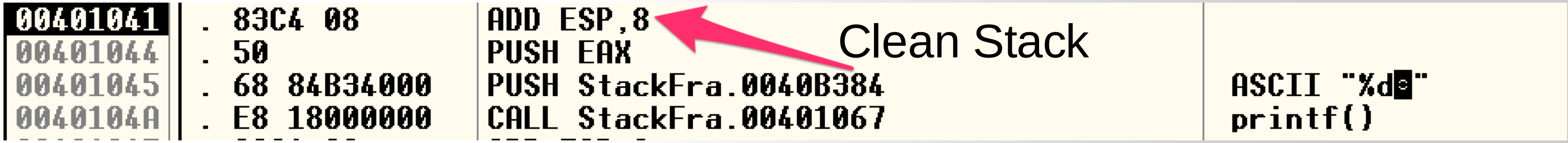



```
00401018 │ . 8BE5        │MOV ESP,EBP
0040101A │ . 5D          │POP EBP
0040101B │└. C3          │RETN
```

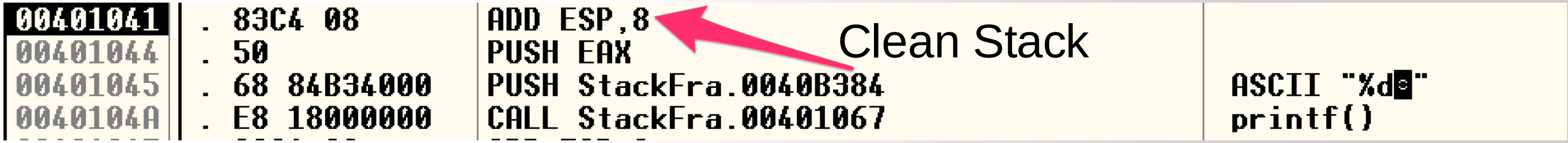
StackFrame.exe



```
00401041  . 83C4 08       ADD ESP,8
00401044  . 50            PUSH EAX
00401045  . 68 84B34000   PUSH StackFra.0040B384          ASCII "%d■"
0040104A  . E8 18000000   CALL StackFra.00401067          printf()
```

Clean Stack

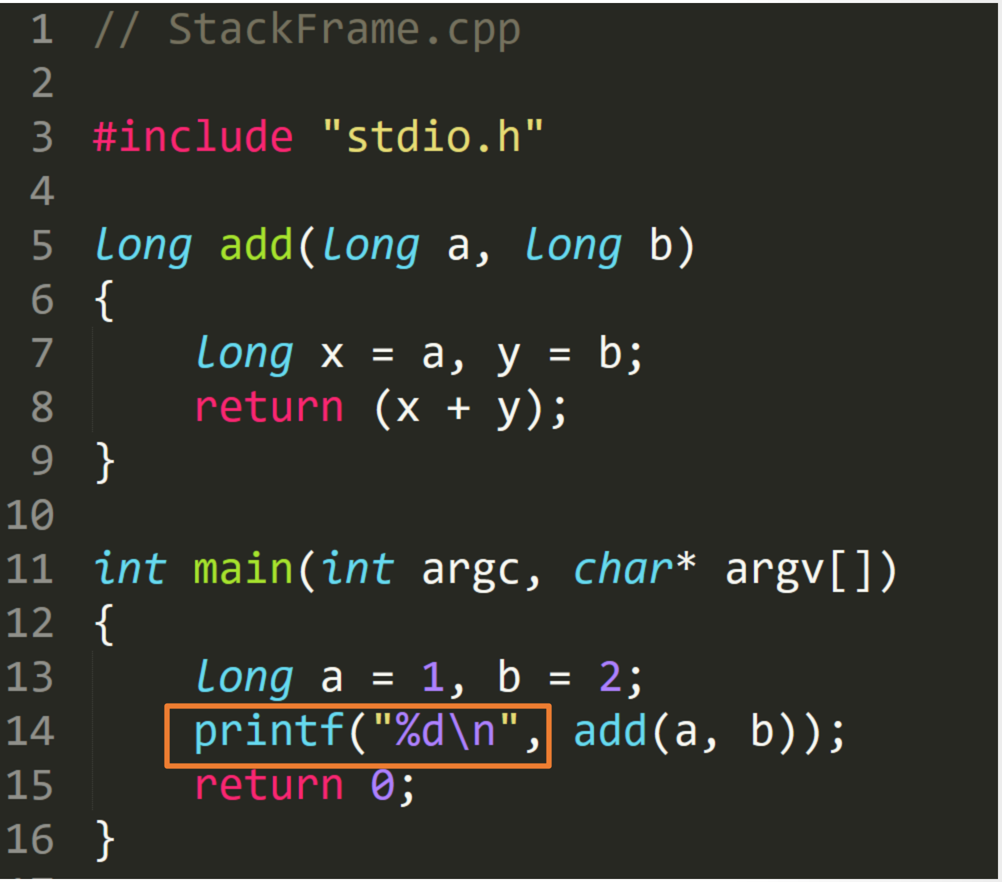
StackFrame.exe



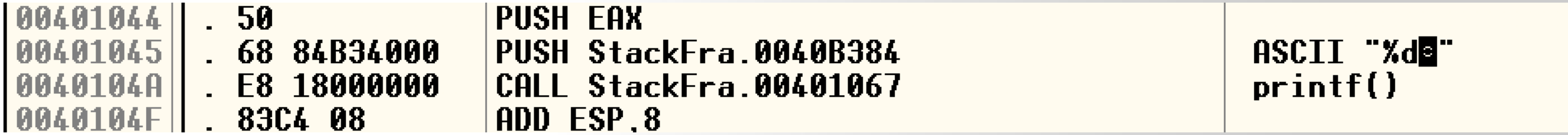
```
00401041  . 83C4 08         ADD ESP,8
00401044  . 50              PUSH EAX
00401045  . 68 84B34000     PUSH StackFra.0040B384        ASCII "%d■"
0040104A  . E8 18000000     CALL StackFra.00401067        printf()
```

Clean Stack

StackFrame.exe

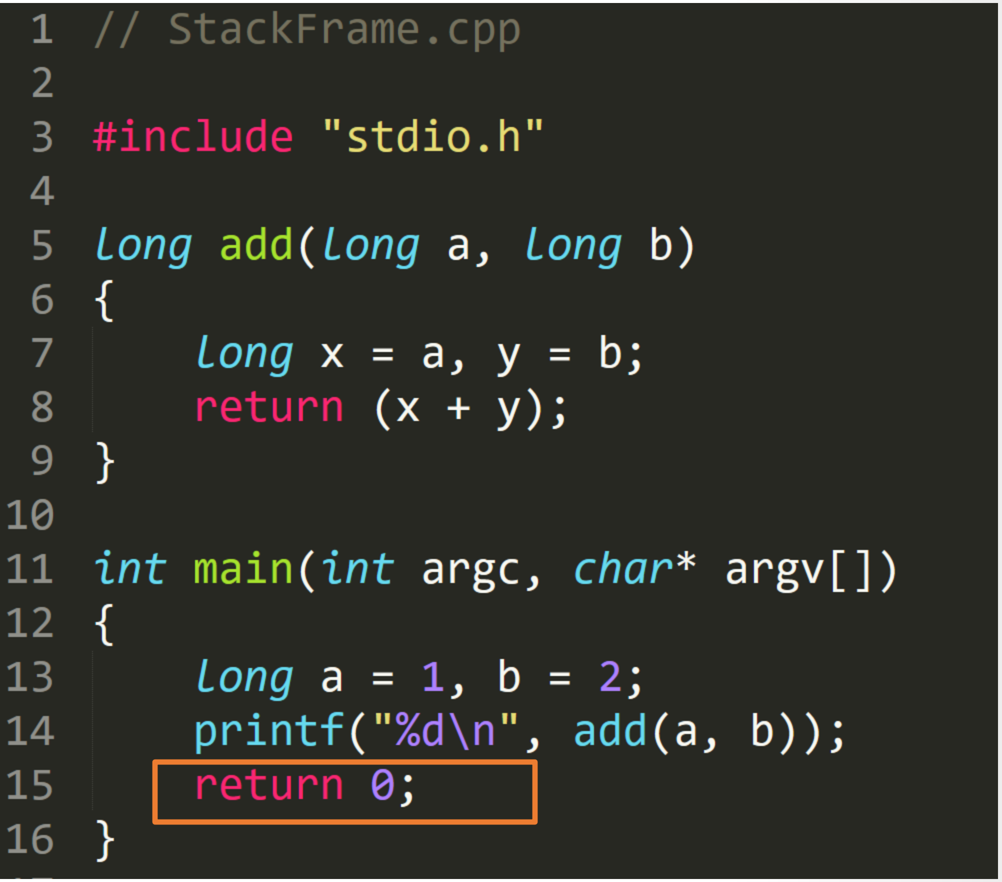


```
// StackFrame.cpp

#include "stdio.h"

long add(long a, long b)
{
    long x = a, y = b;
    return (x + y);
}

int main(int argc, char* argv[])
{
    long a = 1, b = 2;
    printf("%d\n", add(a, b));
    return 0;
}
```

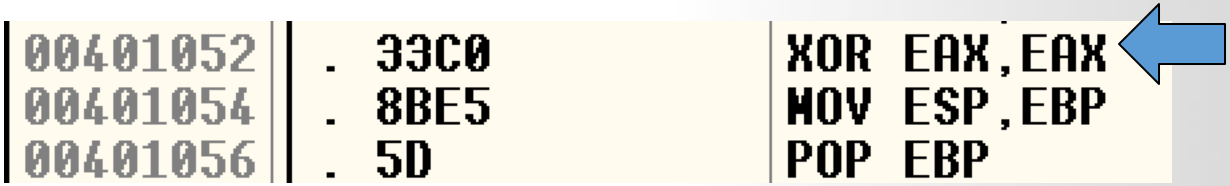


```
00401044  .  50              PUSH EAX
00401045  .  68 84B34000     PUSH StackFra.0040B384             ASCII "%d◙"
0040104A  .  E8 18000000     CALL StackFra.00401067             printf()
0040104F  .  83C4 08         ADD ESP,8
```

StackFrame.exe



```
// StackFrame.cpp

#include "stdio.h"

long add(long a, long b)
{
    long x = a, y = b;
    return (x + y);
}

int main(int argc, char* argv[])
{
    long a = 1, b = 2;
    printf("%d\n", add(a, b));
    return 0;
}
```



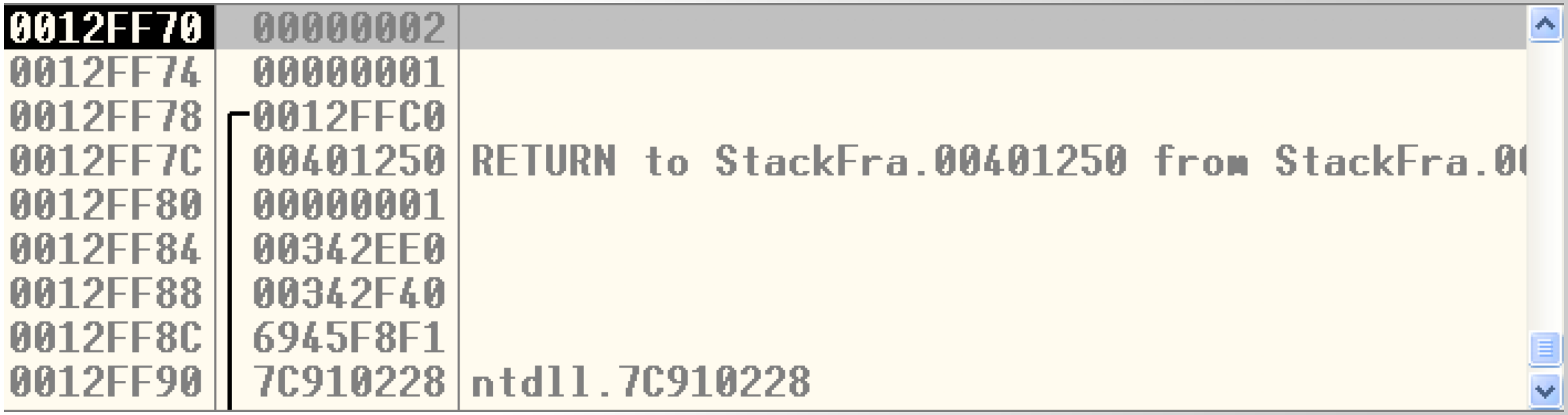
```
00401052  .  33C0     XOR EAX,EAX
00401054  .  8BE5     MOV ESP,EBP
00401056  .  5D       POP EBP
```

Set EAX –> 0
Faster than
MOV EAX,0

Calling Convention

Two Questions

- Q: When a function finished, how to handle the parameter left in the stack.



```
0012FF70   00000002
0012FF74   00000001
0012FF78  ┌0012FFC0
0012FF7C  │00401250  RETURN to StackFra.00401250 from StackFra.0
0012FF80  │00000001
0012FF84  │00342EE0
0012FF88  │00342F40
0012FF8C  │6945F8F1
0012FF90  │7C910228  ntdll.7C910228
```

A: We don’t care…

- Q: When a function finished, how change the ESP value?

A: ESP should be restored to the previous value

Standard C Calling Conventions

- **Calling conventions** are a standardized method for functions to be implemented and called by the machine.
- A calling convention specifies the method that a compiler sets up to access a subroutine.
- There are three major calling conventions that are used with the C language on 32-bit x86 processors:
  - CDECL
  - STDCALL,
  - FASTCALL.

CDECL

- The C language, by default, uses the CDECL calling convention
- In the CDECL calling convention the following holds:
  - Arguments are passed on the stack in Right-to-Left order, and return values are passed in eax.
  - The ***calling* function cleans the stack**. This allows CDECL functions to have *variable-length argument lists*.

STDCALL

- The C language, by default, uses the CDECL calling convention
- In the CDECL calling convention the following holds:
  - Arguments are passed on the stack in Right-to-Left order, and return values are passed in eax.
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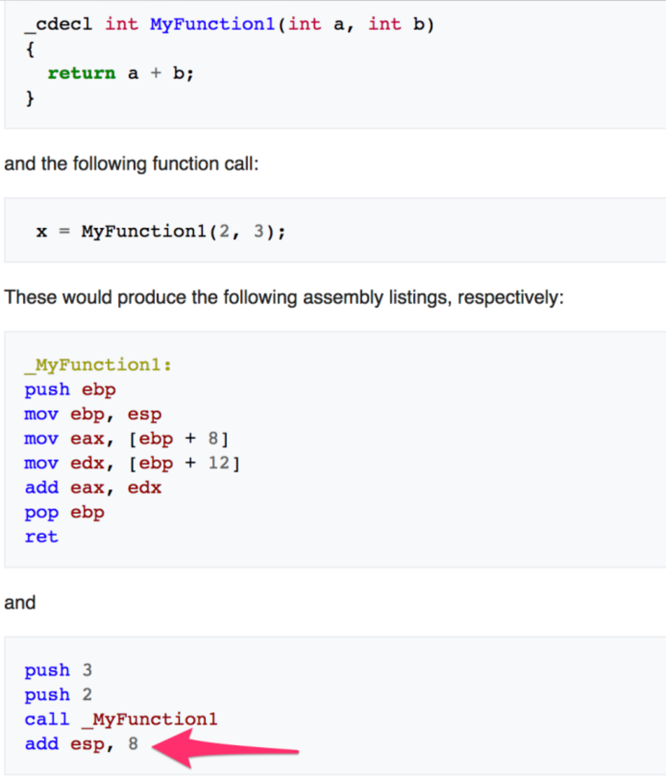

```
_cdecl int MyFunction1(int a, int b)
{
  return a + b;
}
```

and the following function call:

```
 x = MyFunction1(2, 3);
```

These would produce the following assembly listings, respectively:

```
_MyFunction1:
push ebp
mov ebp, esp
mov eax, [ebp + 8]
mov edx, [ebp + 12]
add eax, edx
pop ebp
ret
```

and

```
push 3
push 2
call _MyFunction1
add esp, 8
```

STDCALL

- STDCALL, also known as "WINAPI" (and a few other names, depending on where you are reading it) is used almost exclusively by Microsoft as the standard calling convention for the Win32 API.
  - STDCALL passes arguments right-to-left, and returns the value in eax.
  - The **called function cleans the stack**, unlike CDECL. This means that STDCALL doesn't allow variable-length argument lists.

STDCALL

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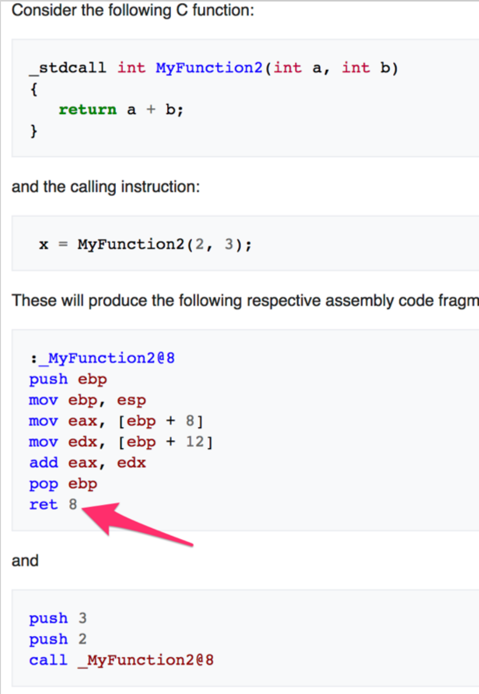
  - STDCALL passes arguments right-to-left, and returns the value in eax.
  - The **called function cleans the stack**, unlike CDECL. This means that STDCALL doesn't allow variable-length argument lists.

RET 8 ➔ RET + POP 8 Byte



Consider the following C function:

```
_stdcall int MyFunction2(int a, int b)
{
   return a + b;
}
```

and the calling instruction:

```
 x = MyFunction2(2, 3);
```

These will produce the following respective assembly code fragm

```
:_MyFunction2@8
push ebp
mov ebp, esp
mov eax, [ebp + 8]
mov edx, [ebp + 12]
add eax, edx
pop ebp
ret 8
```

and

```
push 3
push 2
call _MyFunction2@8
```

FASTCALL

- The FASTCALL calling convention **is not completely standard** across all compilers, so it should be used with caution.
- The calling function most frequently is responsible for cleaning the stack, if needed.

Q & A