Introduction to 8086 Assembly

Lecture 14

Recursion

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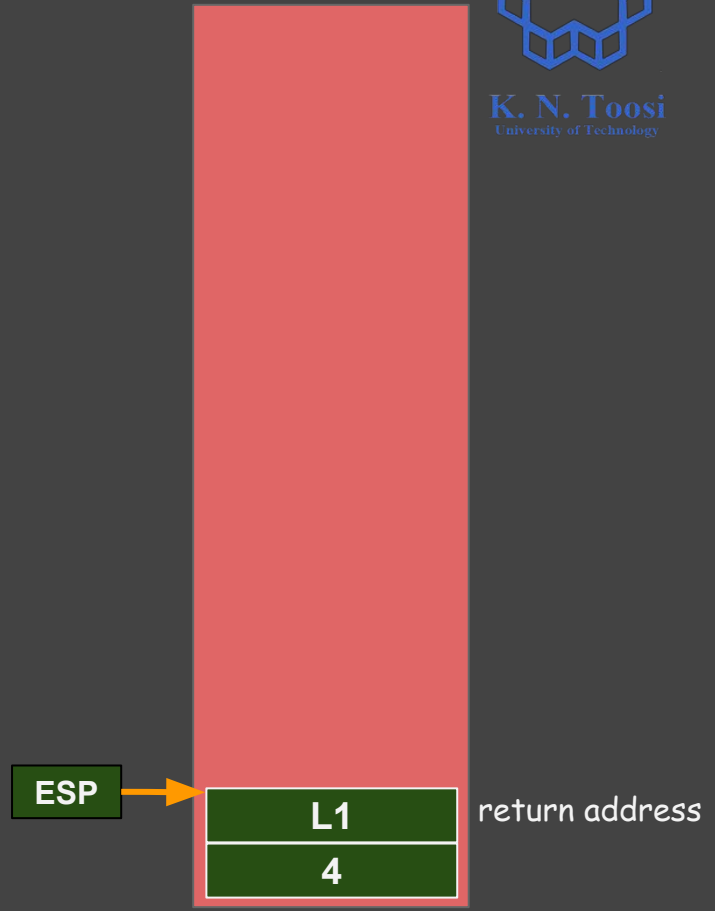

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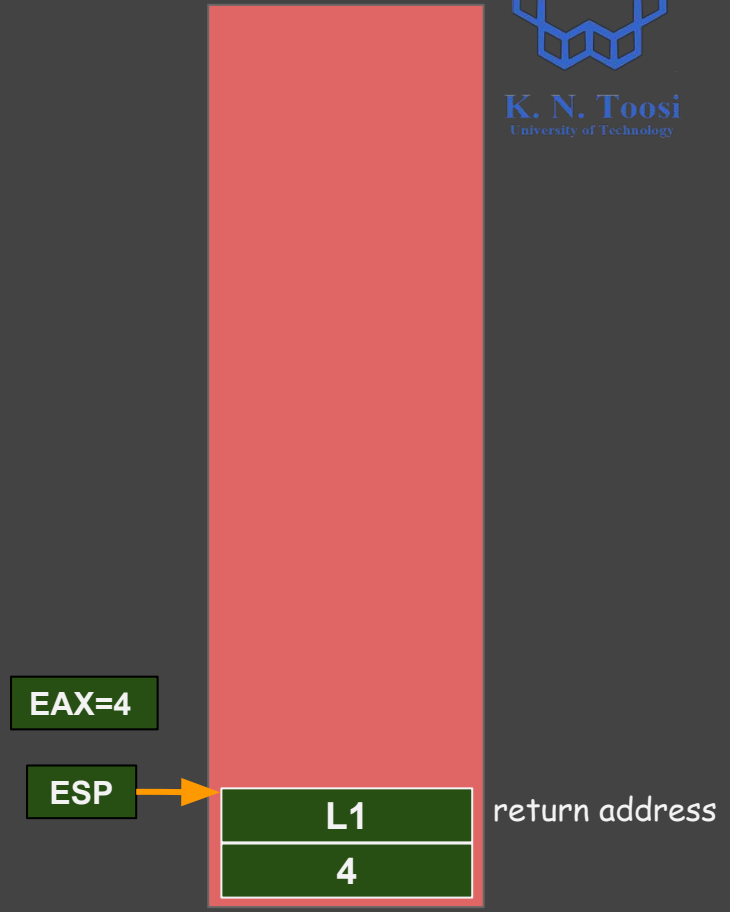

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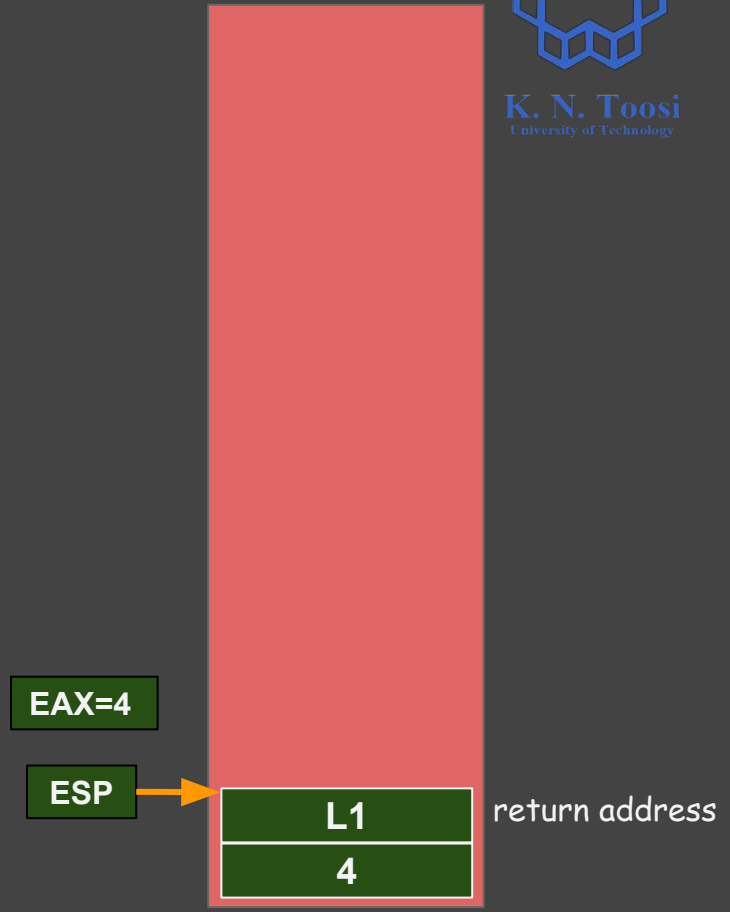

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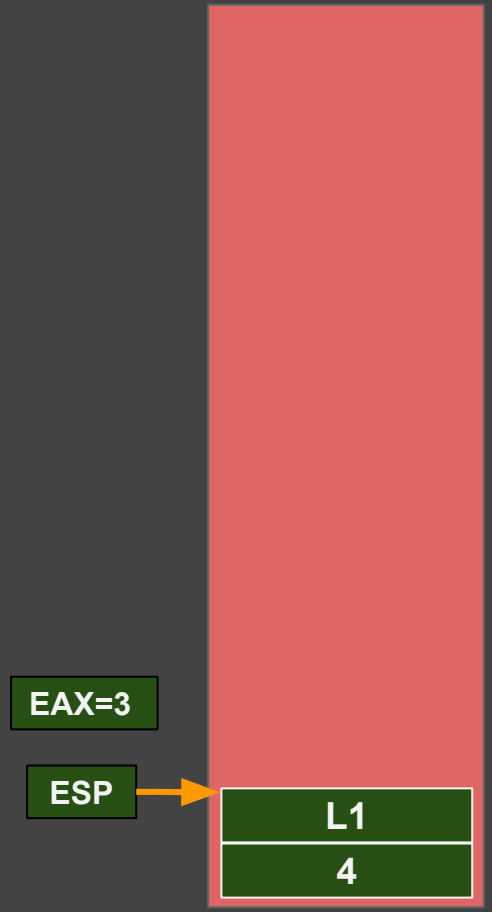

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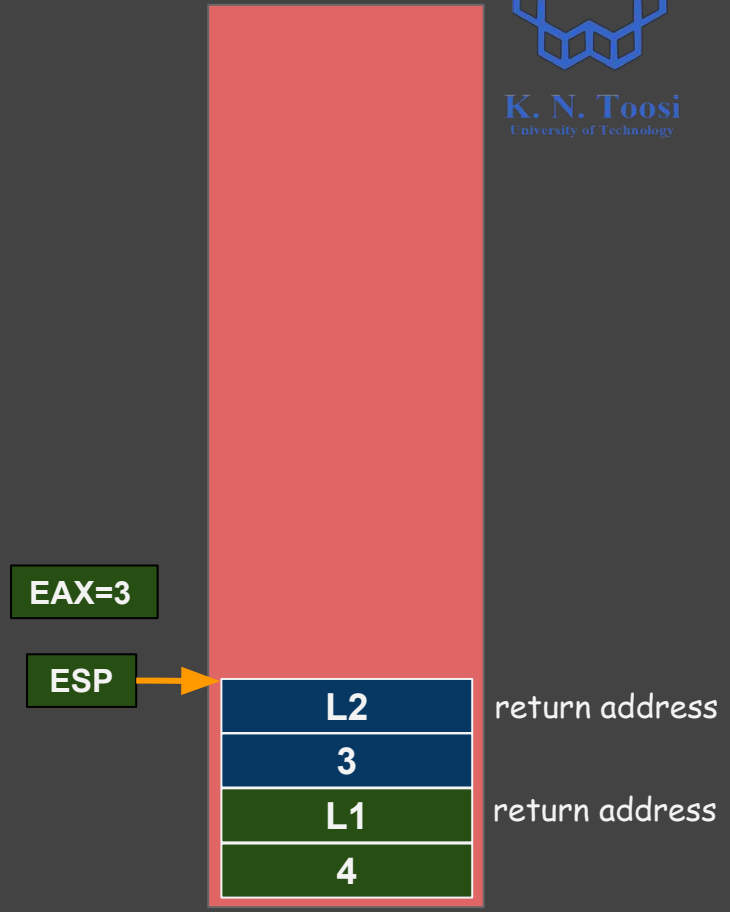

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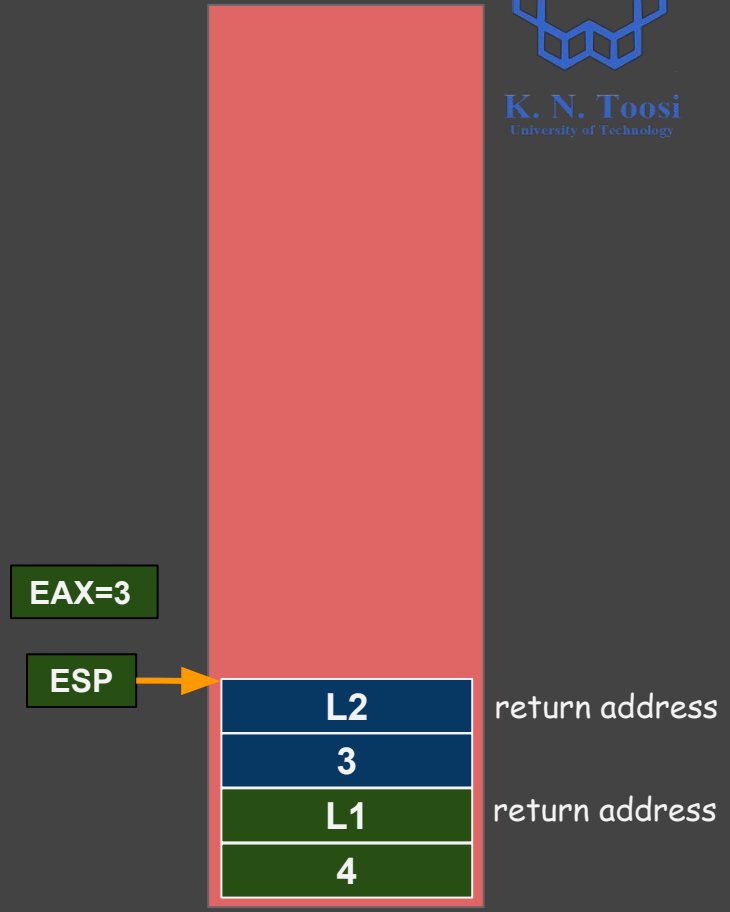

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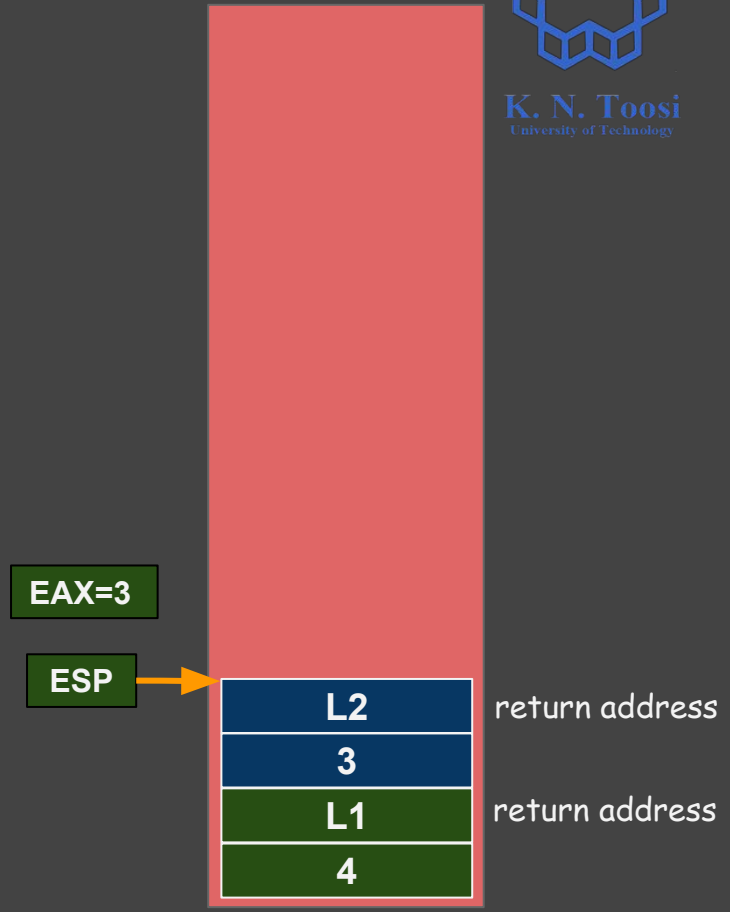

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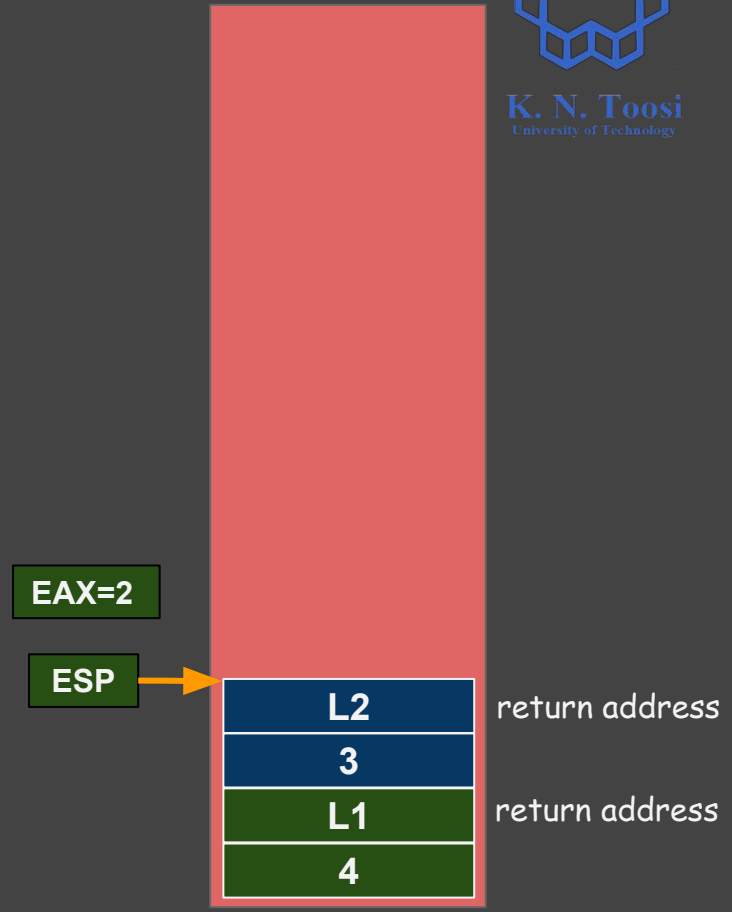

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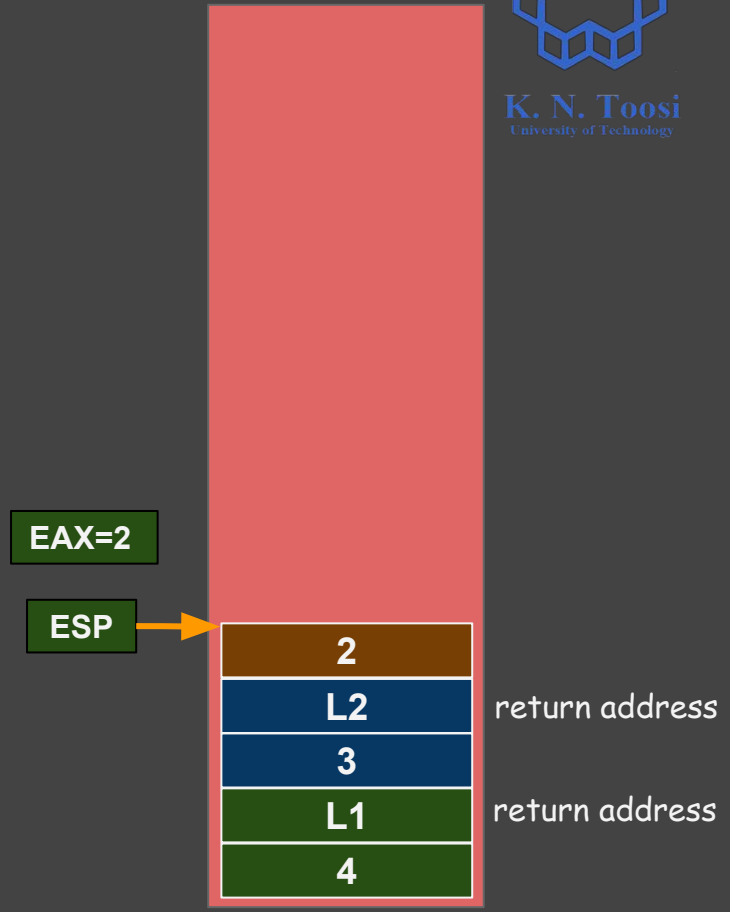

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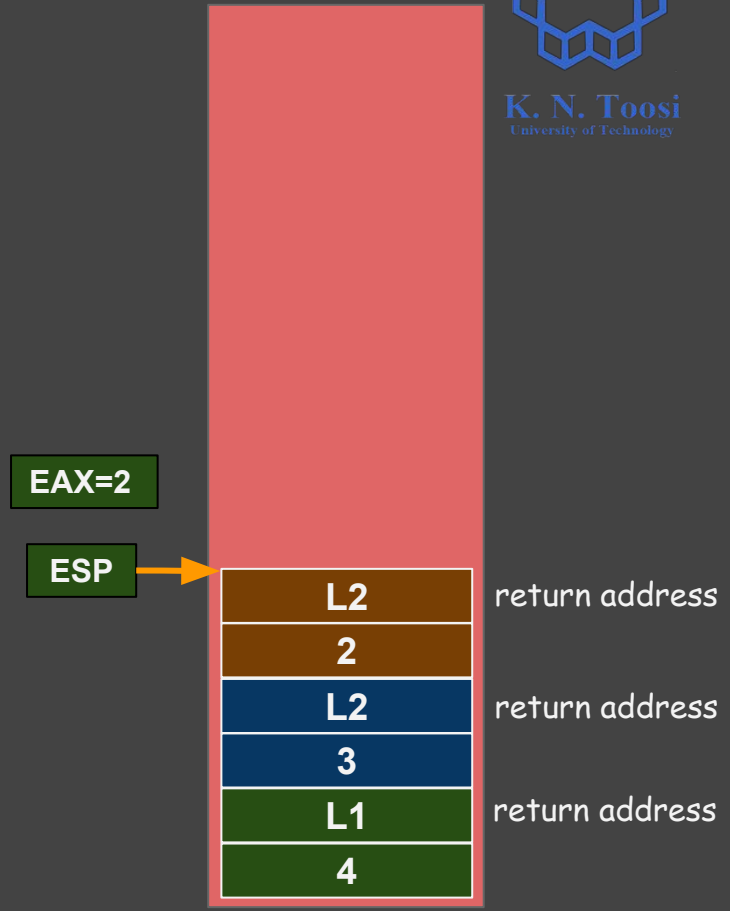

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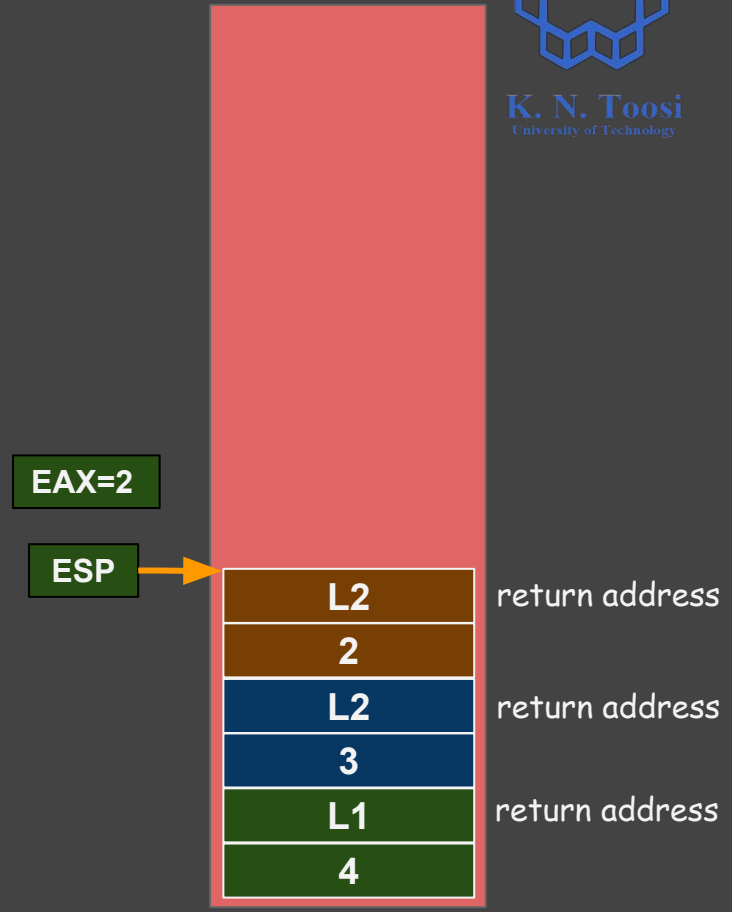

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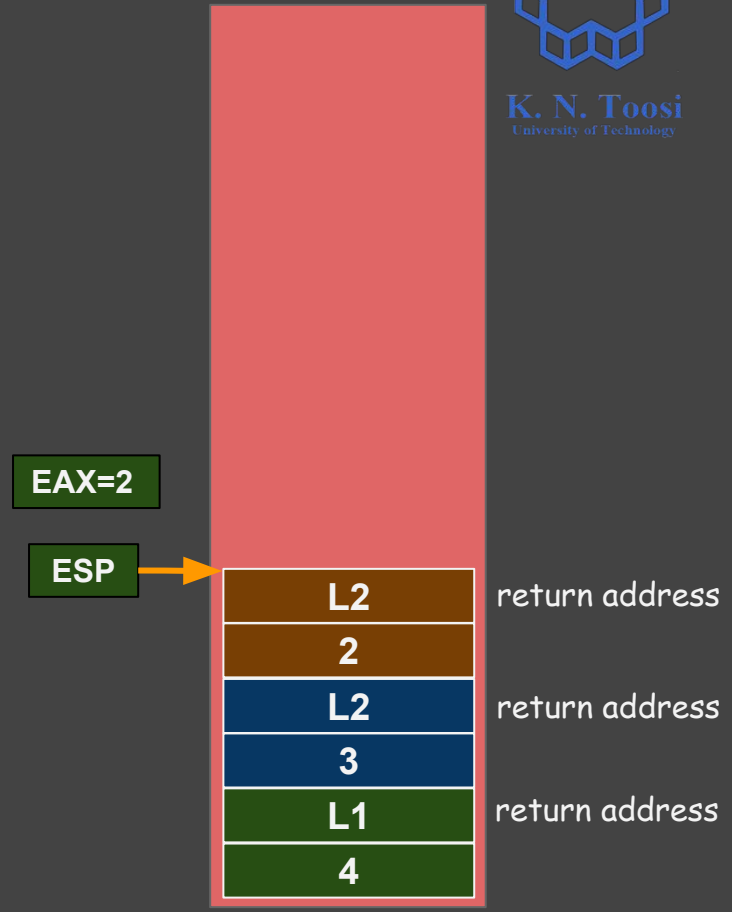

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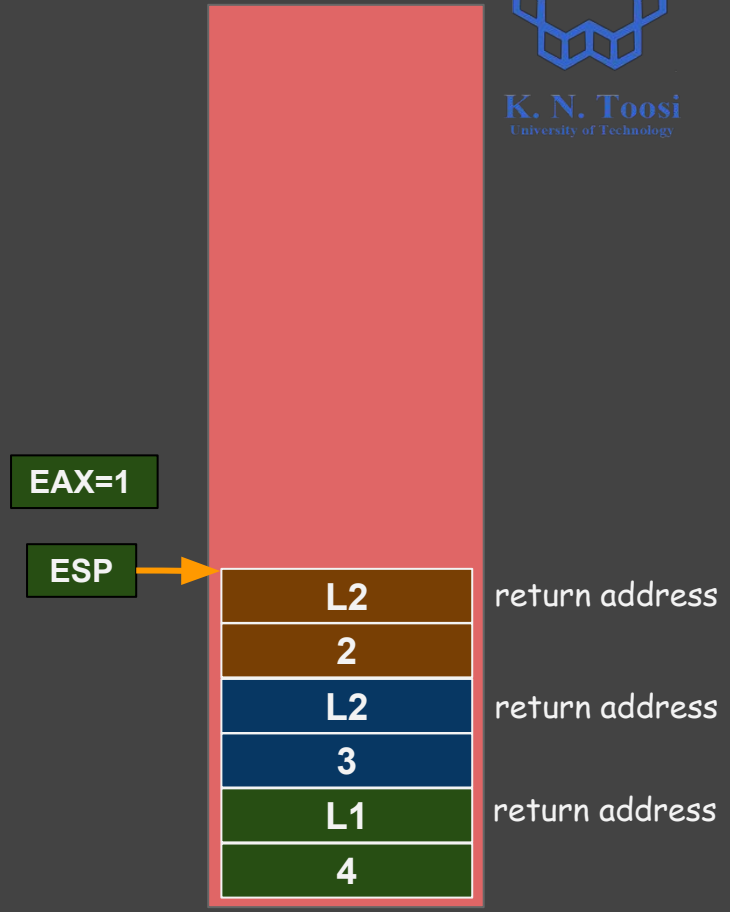

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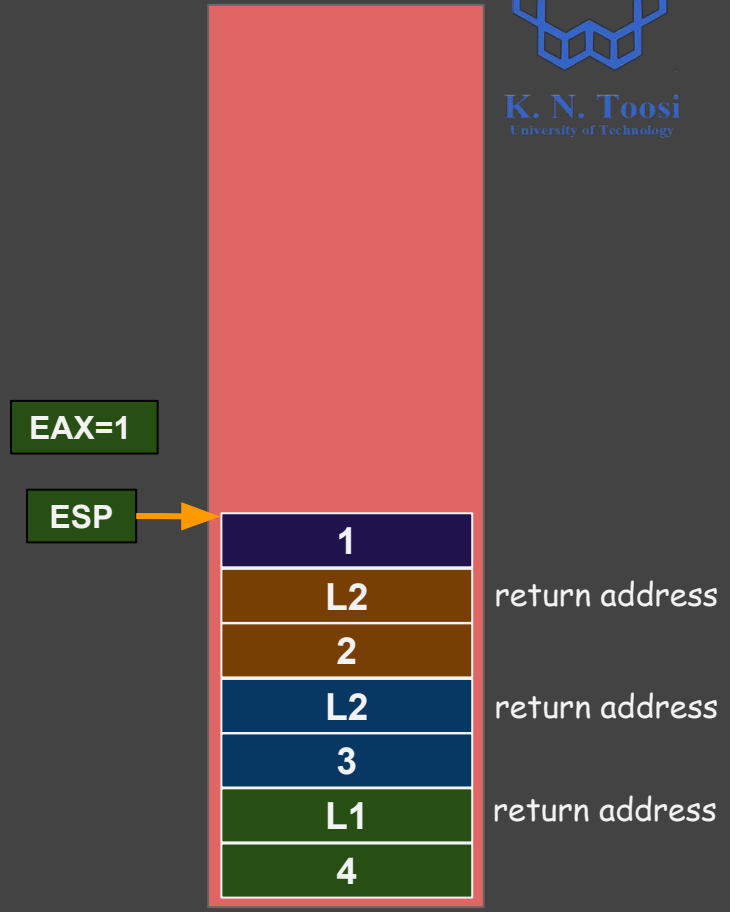

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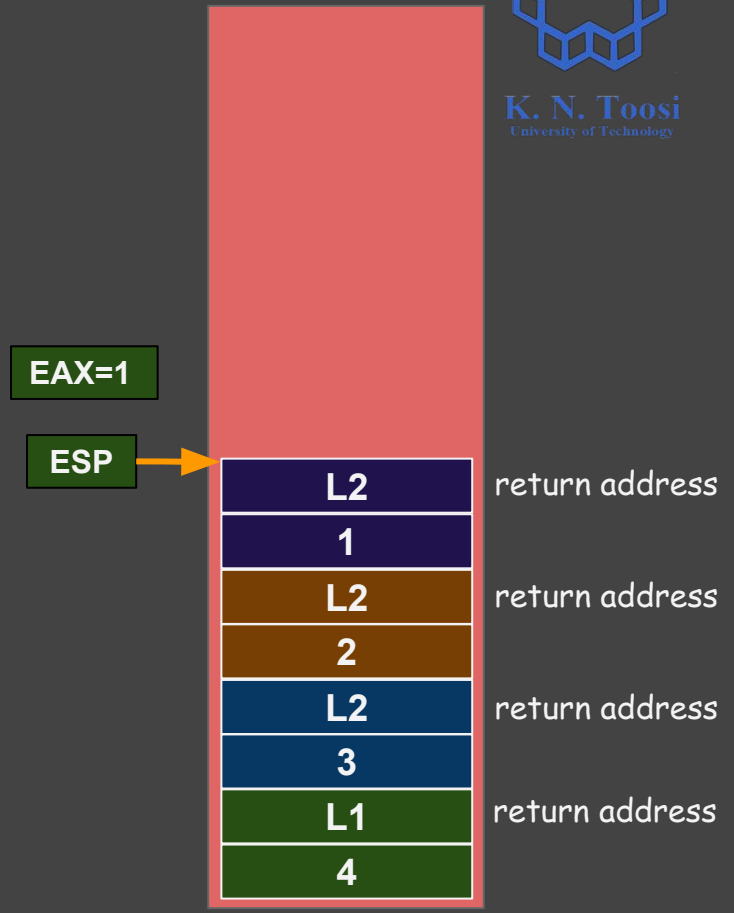

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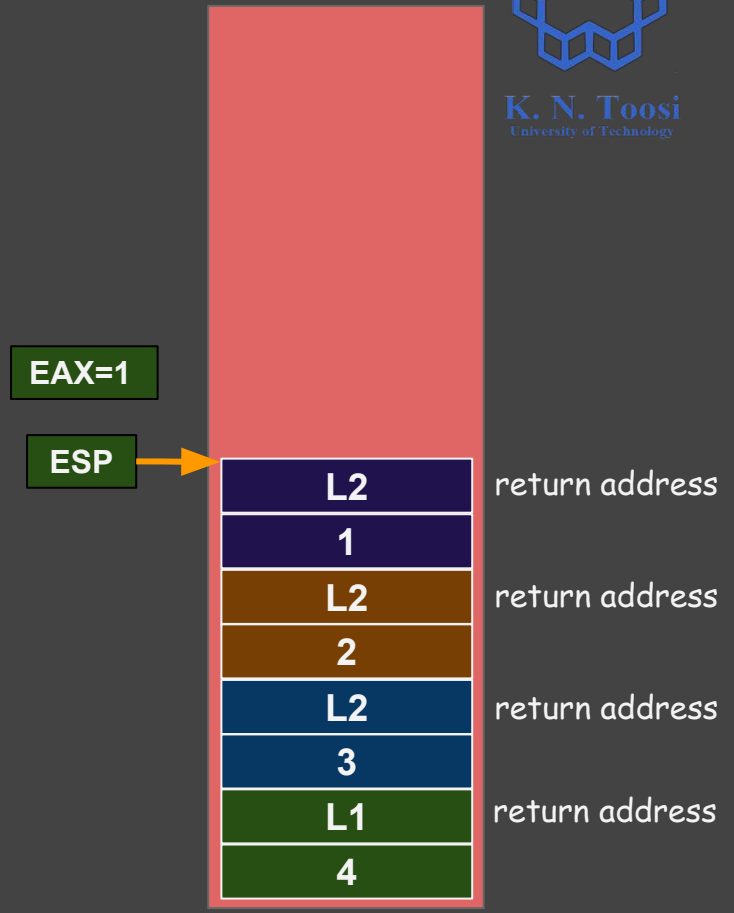

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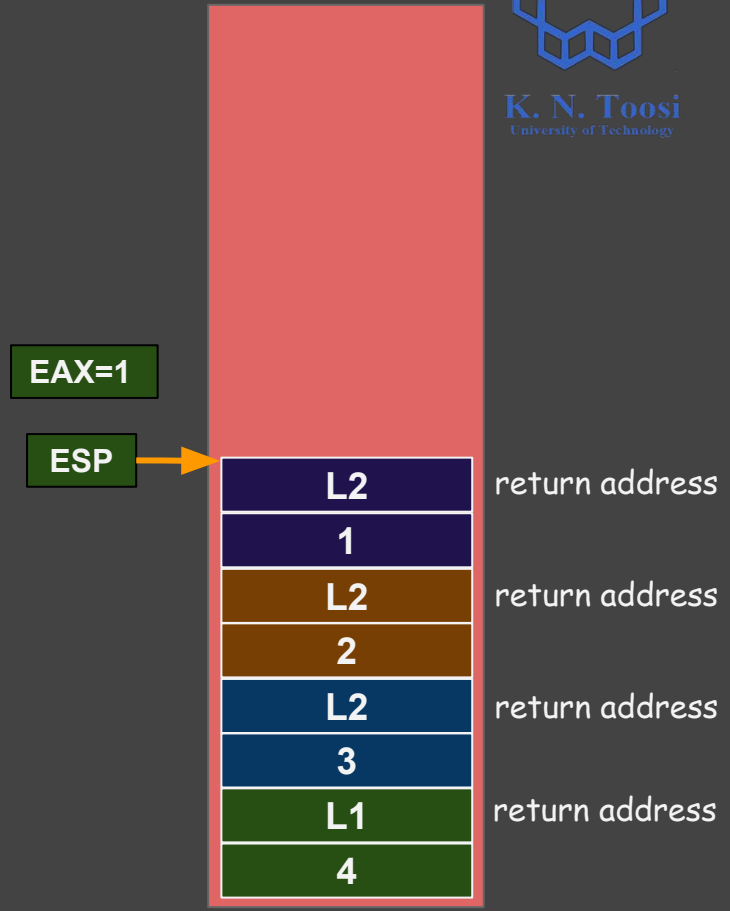

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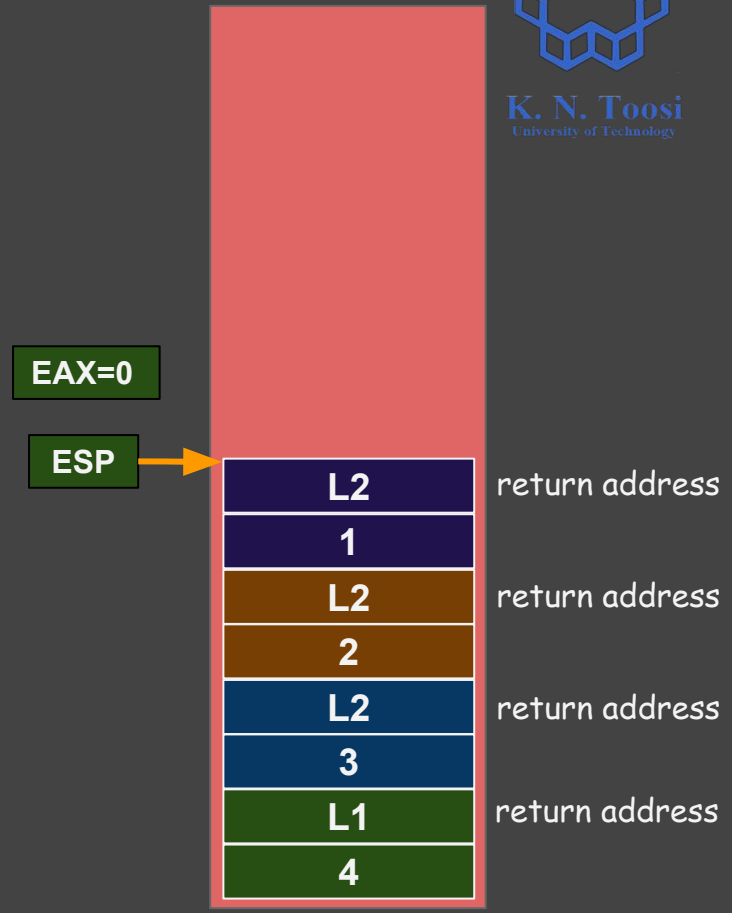

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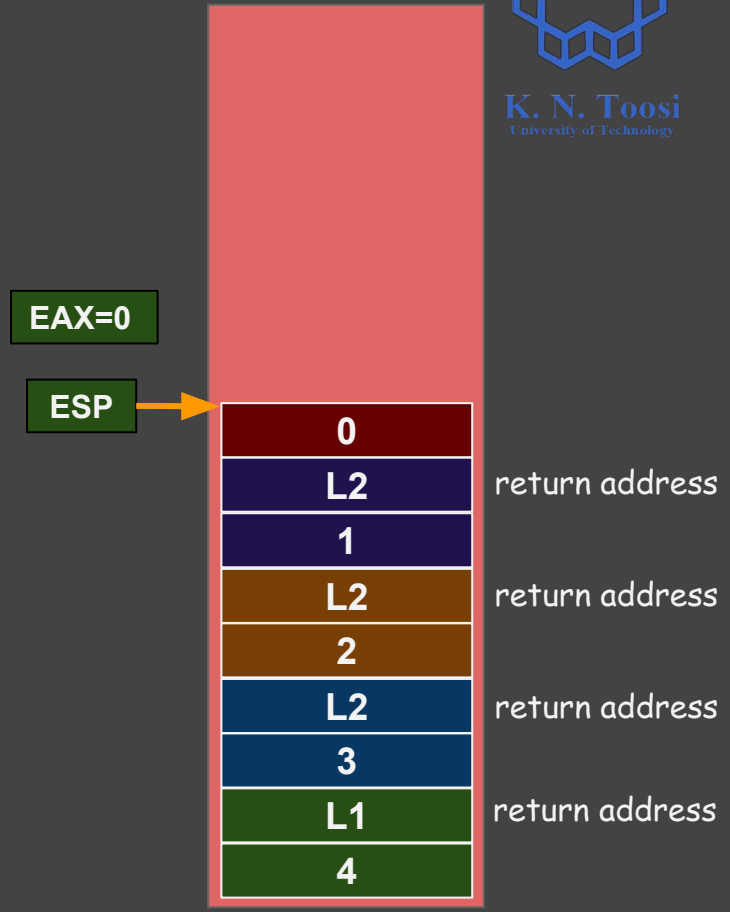

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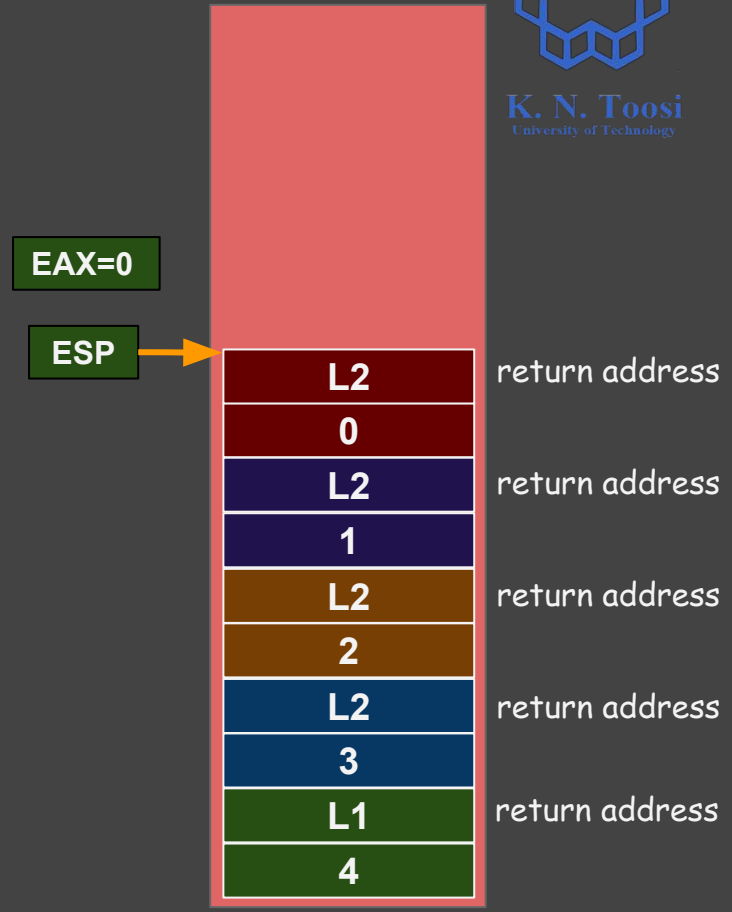

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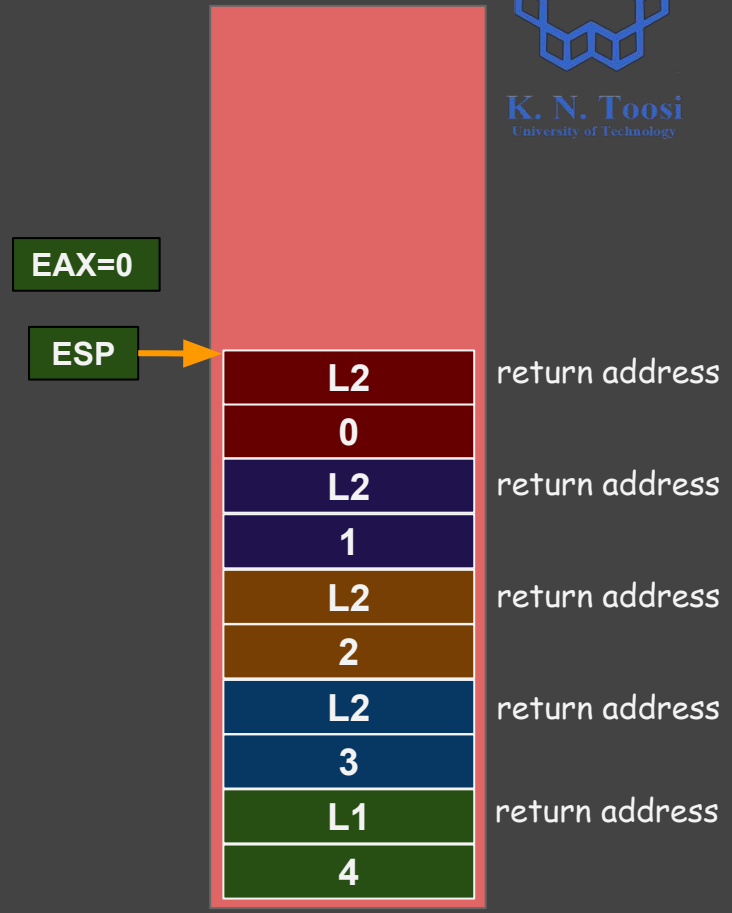

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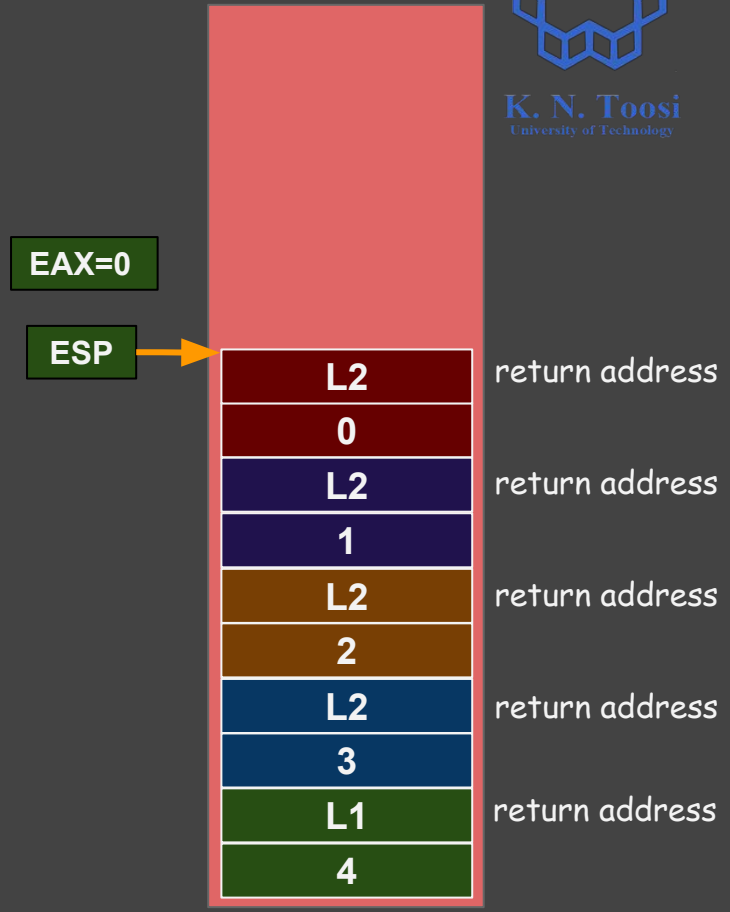

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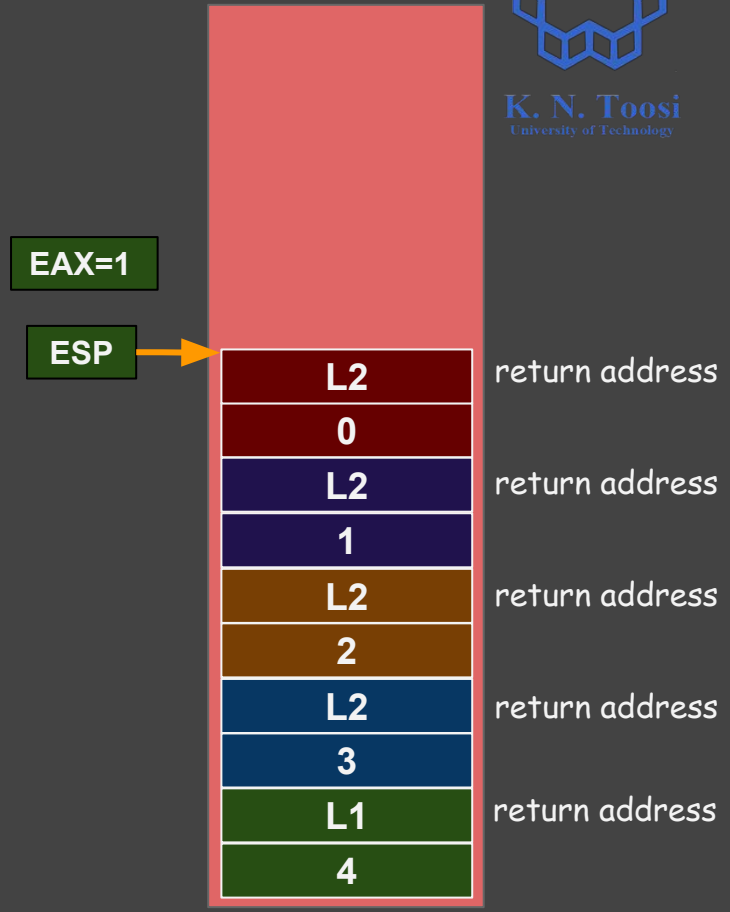

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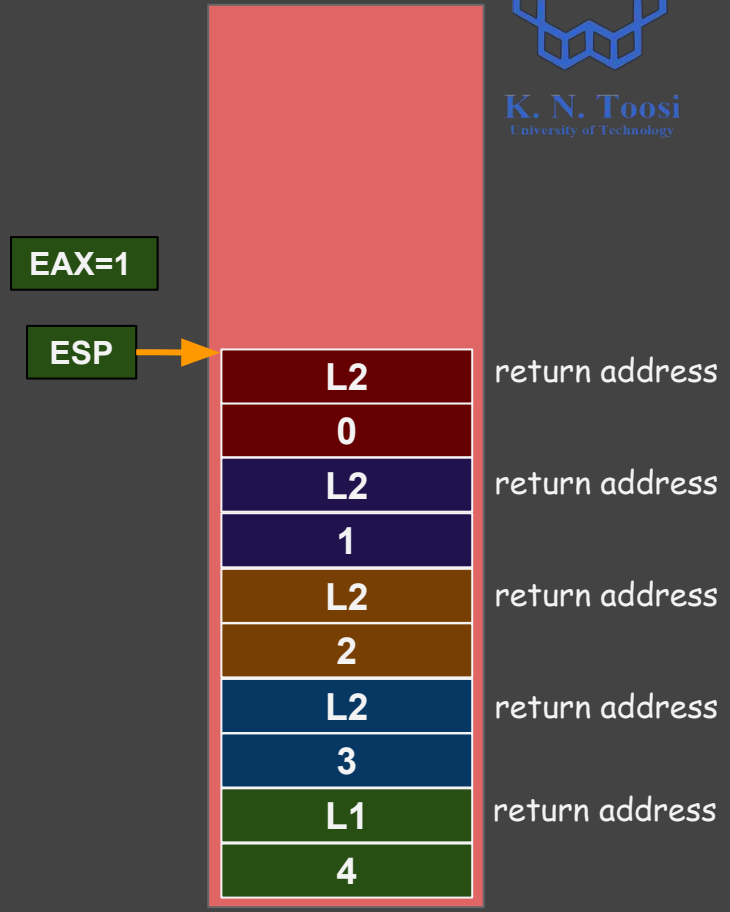

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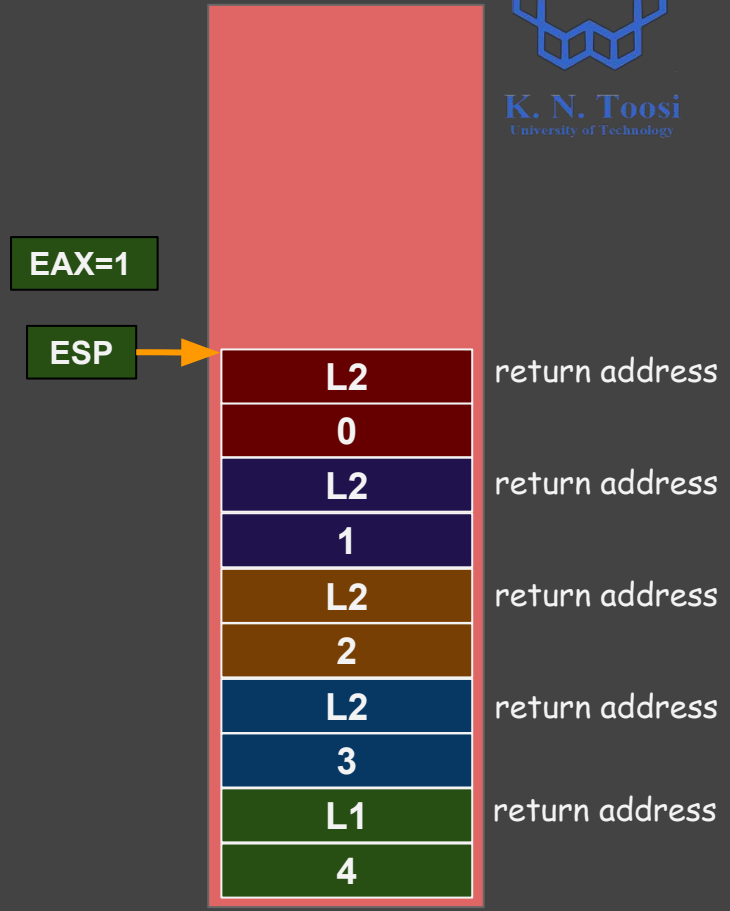
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

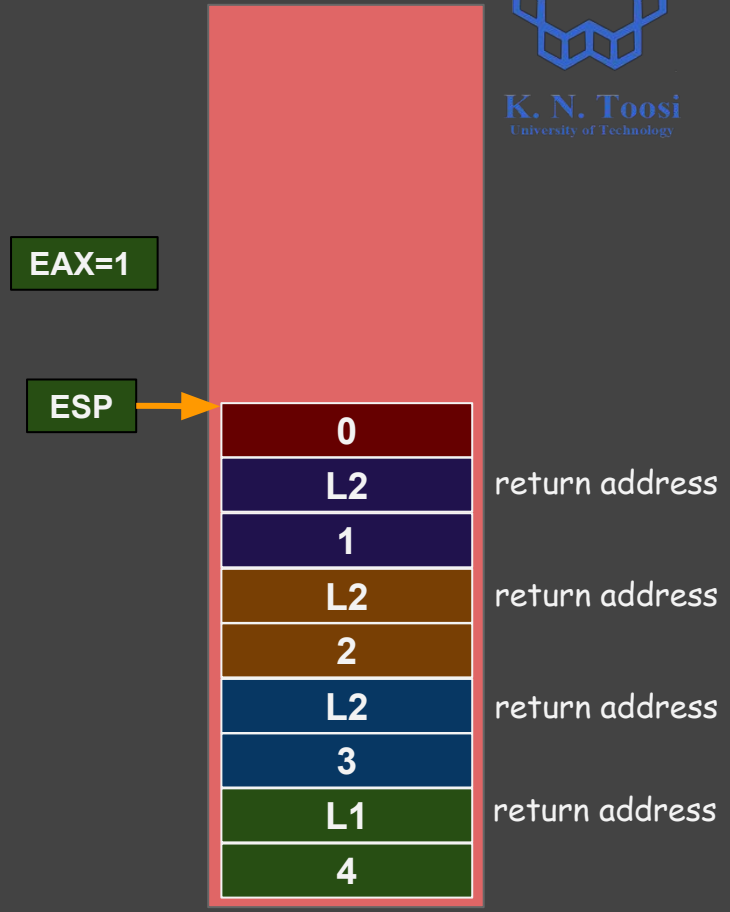
```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

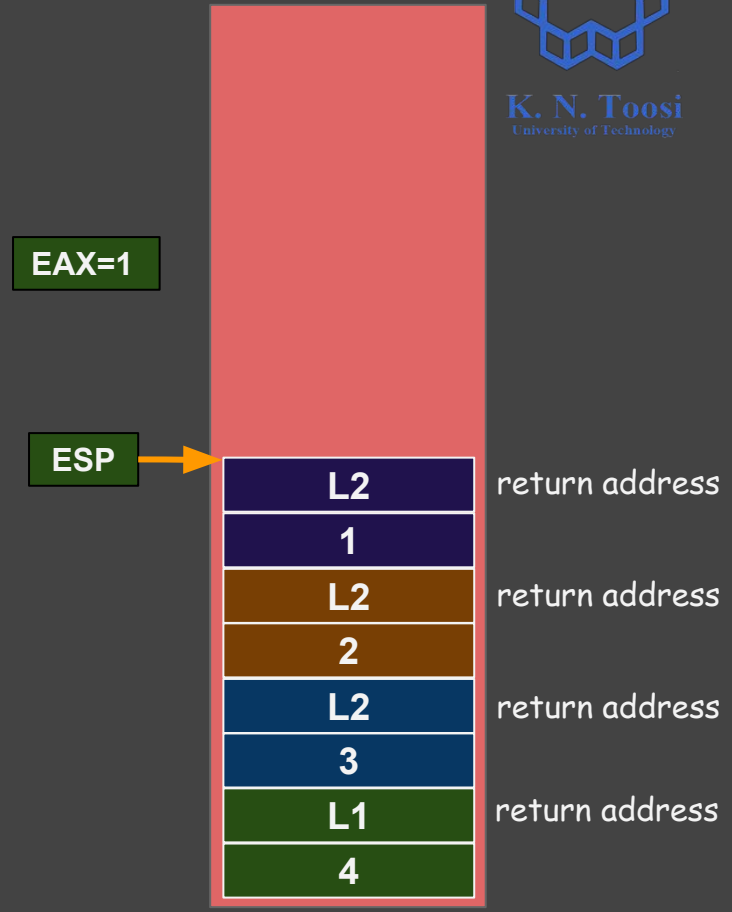
```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

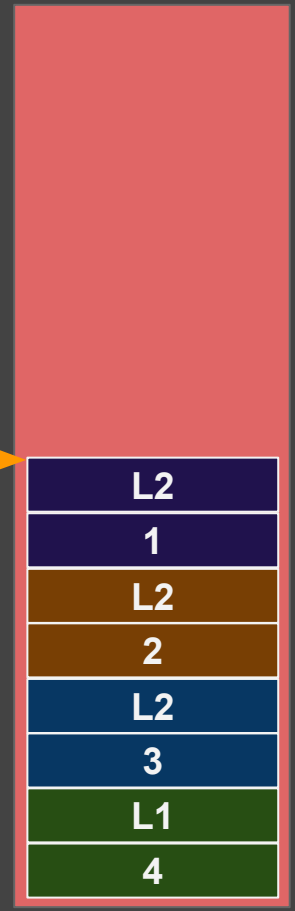
    imul dword [esp+4]

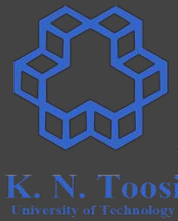
endfact:
    ret
```

EAX=1

EAX*=1

ESP





Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

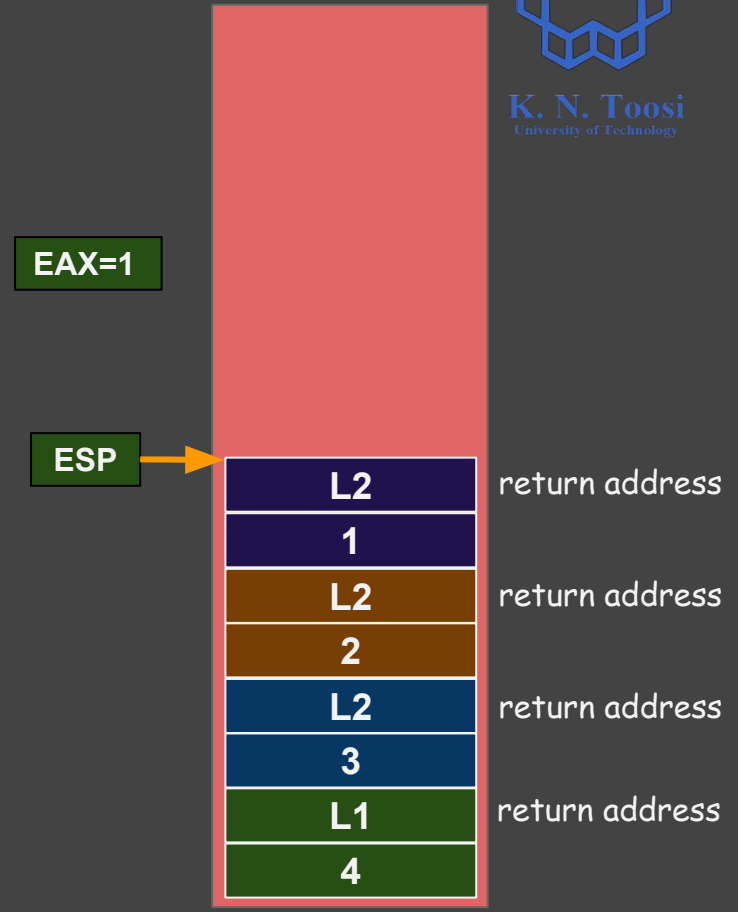
```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

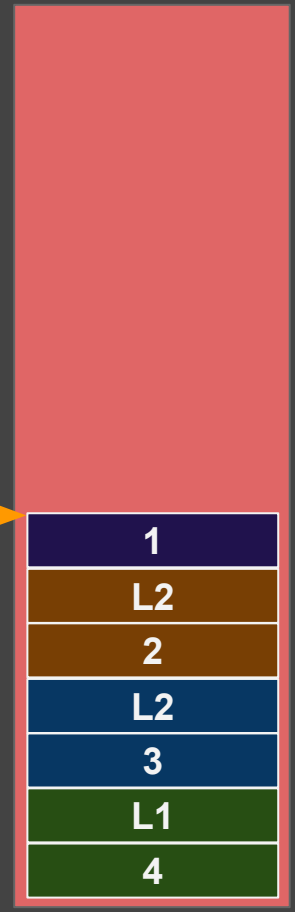
recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```

EAX=1

ESP



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

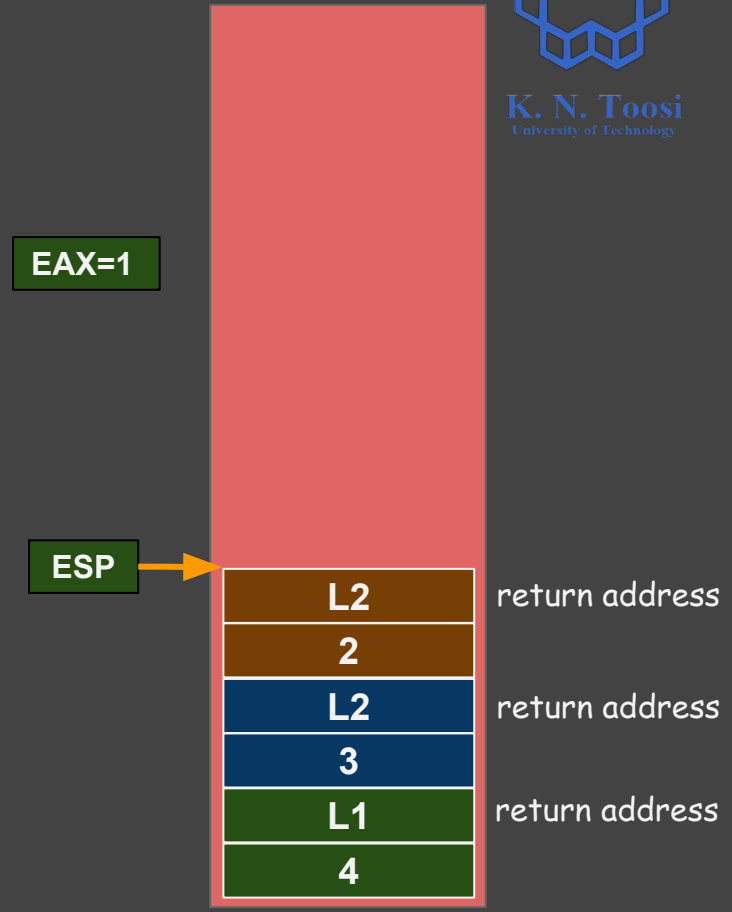
```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

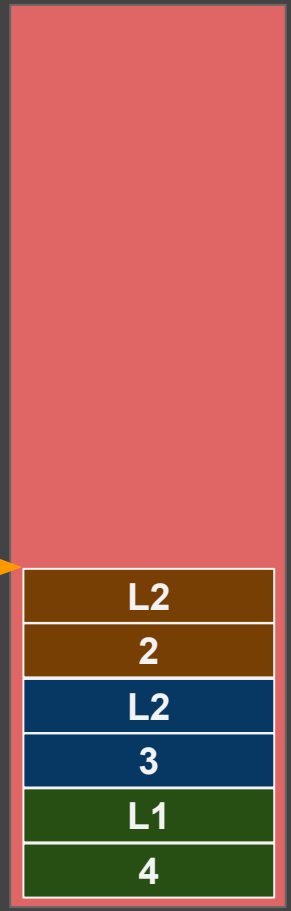
    imul dword [esp+4]

endfact:
    ret
```

EAX*=2

EAX=2

ESP



return address

return address

return address

Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

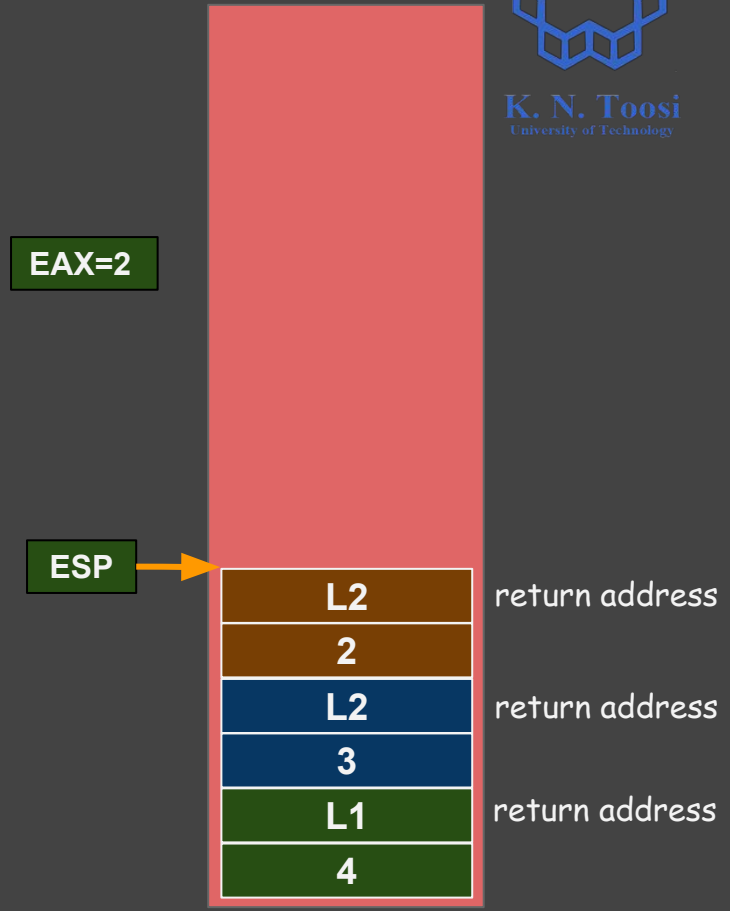
```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

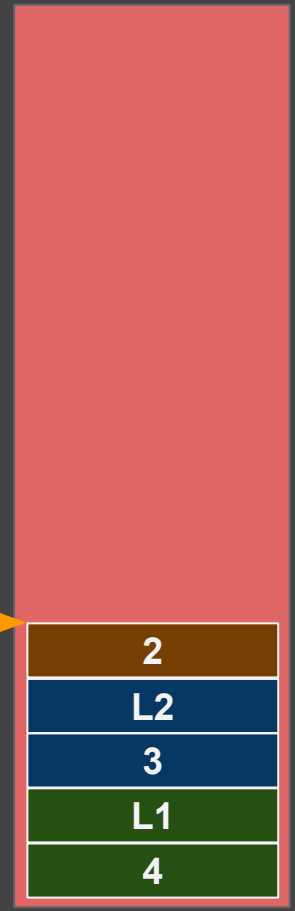
recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```

EAX=2

ESP



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

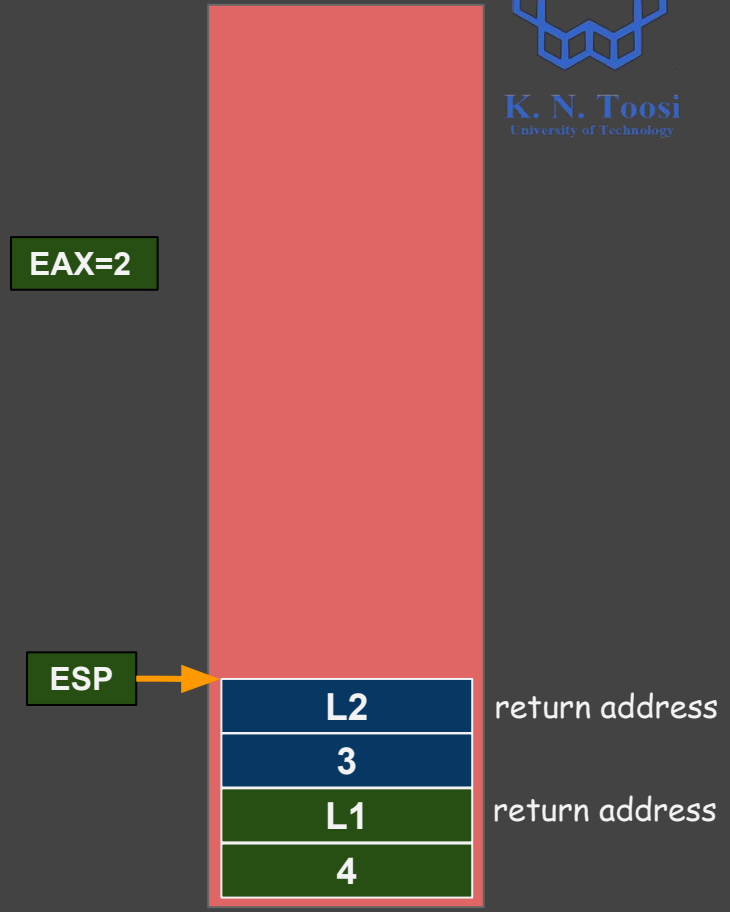
```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

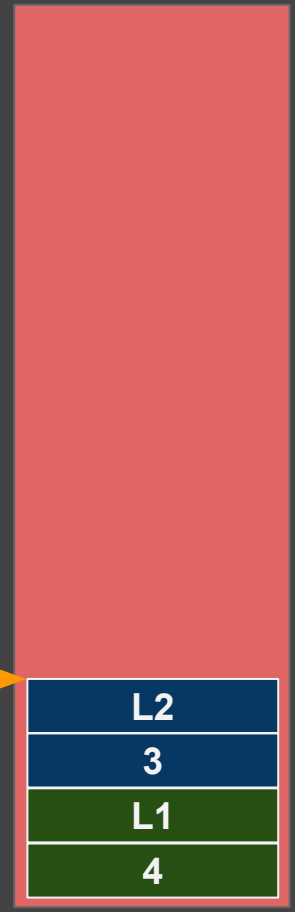
    imul dword [esp+4]

endfact:
    ret
```

EAX=6

EAX*=3

ESP



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

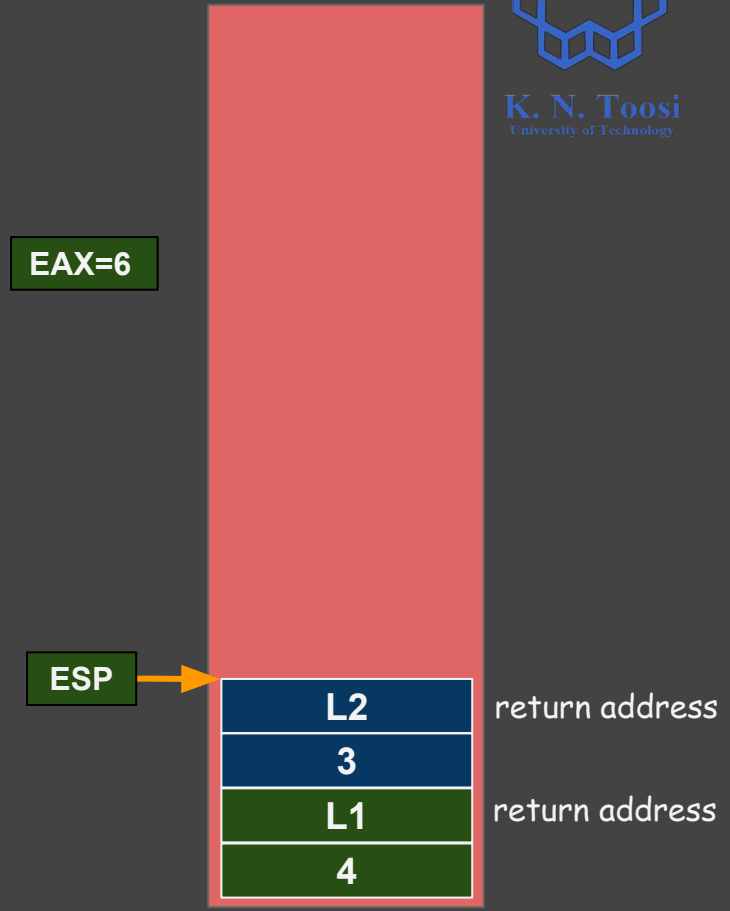
```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```

EAX=6

ESP

return address

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University of Technology

Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

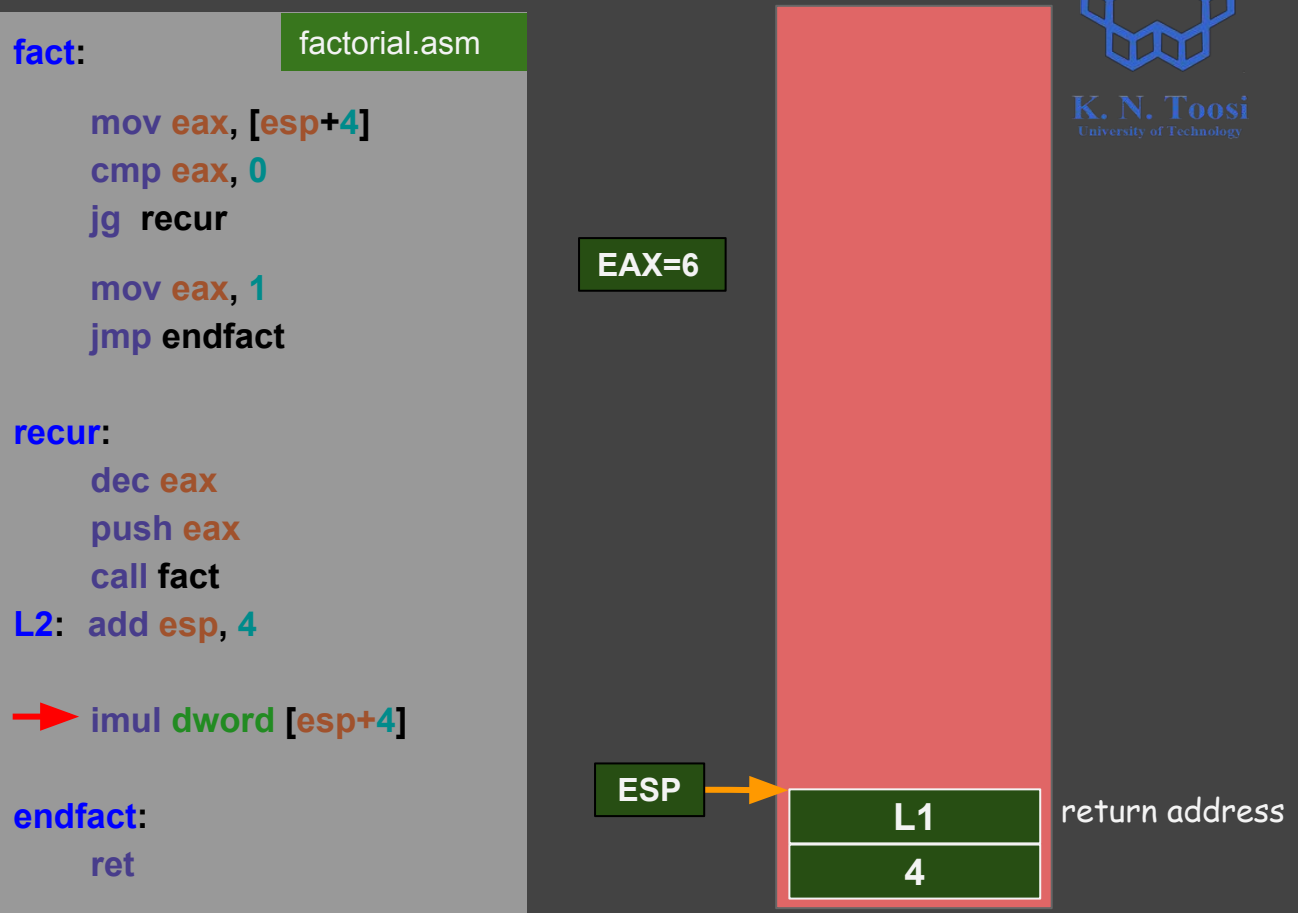
```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```

EAX=24

EAX*=4

ESP

return address

Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

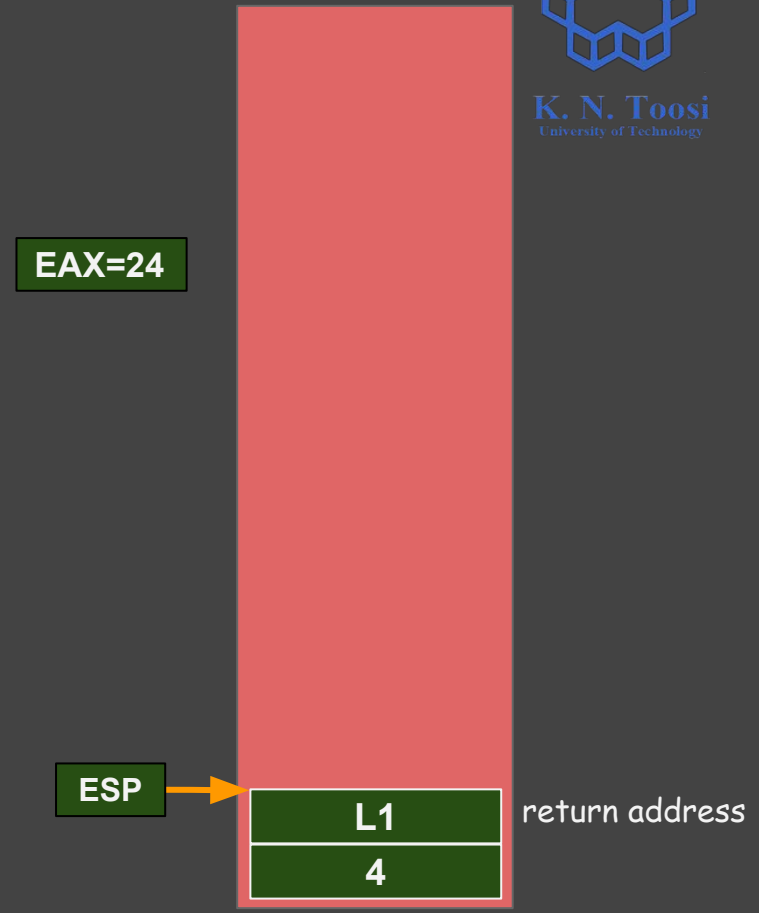
```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

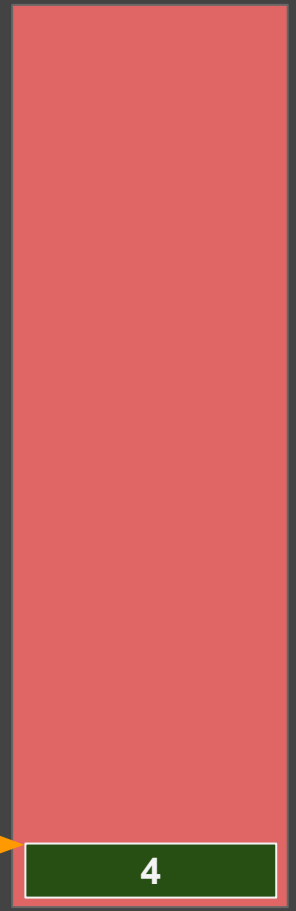
    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```

EAX=24



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

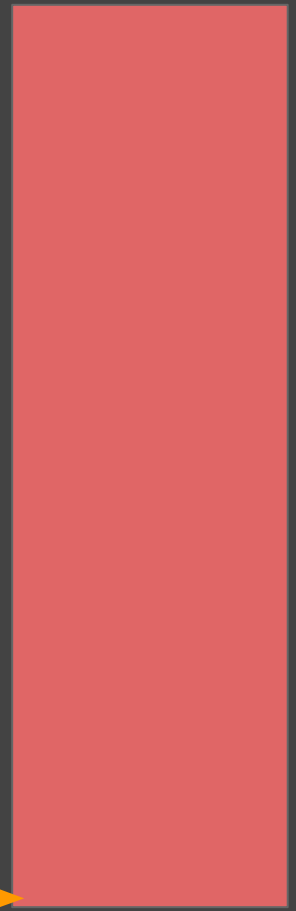
    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```

EAX=24



Recursion

factorial.asm

```
        :
    ;; compute fact(4)
    push 4
    call fact
L1: add esp, 4

    call print_int
    call print_nl
        :
```

factorial.asm

```
fact:
    mov eax, [esp+4]
    cmp eax, 0
    jg  recur

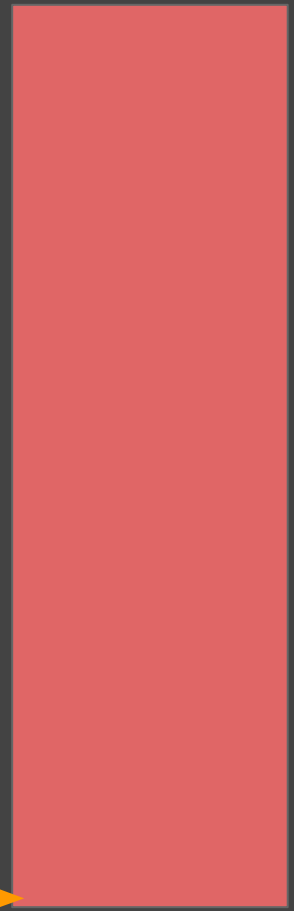
    mov eax, 1
    jmp endfact

recur:
    dec eax
    push eax
    call fact
L2: add esp, 4

    imul dword [esp+4]

endfact:
    ret
```

EAX=24



Practice:

print_int_rec.c

```c
int main() {
  print_integer(12340);
  putchar('\n');

  print_integer(-842101);
  putchar('\n');
}

void print_integer(int n) {
  if (n < 0) {
    putchar('-');
    print_integer(-n);
  }
  else if (n < 10) {
    putchar('0'+n);
    return;
  }
  else {
    print_integer(n / 10);
    putchar('0' + n % 10);
  }
}
```

Practice:

print_int_rec.c

```c
int main() {
  print_integer(12340);
  putchar('\n');

  print_integer(-842101);
  putchar('\n');
}

void print_integer(int n) {
  if (n < 0) {
    putchar('-');
    print_integer(-n);
  }
  else if (n < 10) {
    putchar('0'+n);
    return;
  }
  else {
    print_integer(n / 10);
    putchar('0' + n % 10);
  }
}
```

print_int_rec.asm

```asm
section .data
c:    db   0

section .text

myputchar:
      pusha

      mov  [c], al
      mov  ecx, c  ; address of start of message
      mov  edx, 1  ; length of message
      mov  ebx,1   ; file descriptor (1: stdout)
      mov  eax,4   ; syscall number  (4: sys_write)
      int  0x80

      popa
      ret
```

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University of Technology

Practice:

print_int_rec.c

```c
int main() {
  print_integer(12340);
  putchar('\n');

  print_integer(-842101);
  putchar('\n');
}

void print_integer(int n) {
  if (n < 0) {
    putchar('-');
    print_integer(-n);
  }
  else if (n < 10) {
    putchar('0'+n);
    return;
  }
  else {
    print_integer(n / 10);
    putchar('0' + n % 10);
  }
}
```

print_int_rec.asm (cont.)

```
global _start

_start:
    push 12340
    call print_integer
    ;; callee clears the stack

    mov al, 10
    call myputchar

    push -842101
    call print_integer

    mov al, 10
    call myputchar

    push 0
    call print_integer

    mov al, 10
    call myputchar

    mov eax, 1
    int 0x80
```

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Practice:

print_int_rec.c

```c
int main() {
  print_integer(12340);
  putchar('\n');

  print_integer(-842101);
  putchar('\n');
}

void print_integer(int n) {
  if (n < 0) {
    putchar('-');
    print_integer(-n);
  }
  else if (n < 10) {
    putchar('0'+n);
    return;
  }
  else {
    print_integer(n / 10);
    putchar('0' + n % 10);
  }
}
```

print_int_rec.asm (cont.)

```asm
print_integer:
    push ebp
    mov  ebp, esp
    pusha

    mov eax, [ebp+8]

    cmp eax , 0
    jnl check2

    mov  al, '-'
    call myputchar
    mov eax, [ebp+8]

    neg  eax
    push eax
    call print_integer
    jmp endfunc
check2:
    cmp eax, 10
    jge recur

    add  al, '0'
    call myputchar
    jmp endfunc
```

print_int_rec.asm (cont.)

```asm
recur:
    mov edx, 0
    mov ecx, 10
    div ecx

    push eax
    call print_integer

    mov al, dl
    add al, '0'
    call myputchar

endfunc:
    popa
    mov esp, ebp
    pop ebp
    ret 4
```

Practice:

print_int_rec.c

```c
int main() {
  print_integer(12340);
  putchar('\n');

  print_integer(-842101);
  putchar('\n');
}

void print_integer(int n) {
  if (n < 0) {
    putchar('-');
    print_integer(-n);
  }
  else if (n < 10) {
    putchar('0'+n);
    return;
  }
  else {
    print_integer(n / 10);
    putchar('0' + n % 10);
  }
}
```

print_int_rec.asm (cont.)

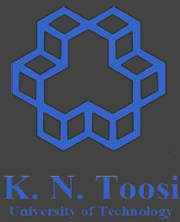
```
print_integer:
    push ebp
    mov  ebp, esp
    pusha

    mov eax, [ebp+8]

    cmp eax , 0
    jnl check2

    mov  al, '-'
    call myputchar
    mov eax, [ebp+8]

    neg  eax
    push eax
    call print_integer
    jmp endfunc
check2:
    cmp eax, 10
    jge recur

    add  al, '0'
    call myputchar
    jmp endfunc
```

print_int_rec.asm (cont.)

```
recur:
    mov edx, 0
    mov ecx, 10
    div ecx

    push eax
    call print_integer

    mov al, dl
    add al, '0'
    call myputchar

endfunc:
    popa
    mov esp, ebp
    pop ebp
    ret 4
```

```
b.nasihatkon@kntu:lecture14$ ./a.out
12340
-842101
0
```

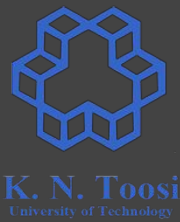
Indirect call



jmp label1

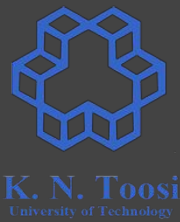
call label1

Indirect call



jmp eax
call eax

Indirect call

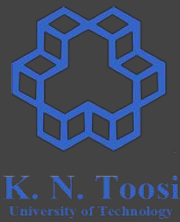


jmp eax
call eax

jmp [label]
call [label]

jmp [eax]
call [eax]

Indirect call



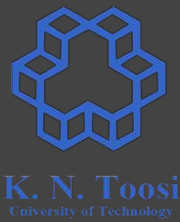
jmp eax
call eax

jmp [label]
call [label]

jmp [eax]
call [eax]

Applications?

Indirect call




```
jmp eax
call eax

jmp [label]
call [label]

jmp [eax]
call [eax]
```

Applications?

pointer to functions