Oregon State University

COLLEGE OF ENGINEERING | School of Electrical Engineering and Computer Science

CS 161

Introduction to CS I

Lecture 21

- Recursion

Assignment 5 – Treasure Chest

- Define your own struct (type) with at least 4 attributes
- Create a program to store items of that type in a treasure chest and keep track of the total collection value
- User can:
  - Add item
  - Remove item
  - Display item
  - Add an item with random properties
  - <Your choice here>

No live demo
(README.txt instead)

Midterm 2

- Midterm 2: content through **week 7** (but no structs)
- Review questions (and solutions) are on course website
- Bring your questions to class on Wednesday
  - Stuck on pointers? Functions? 2D arrays?
- Review session: Thursday 2/27, 6-7 p.m., **LINC 228**
- Midterm: Friday 2/28, 2-2:50 p.m., LINC 100
- Format: true/false, multiple choice, one page short answer
  - Scantron sheet: fill in bubbles with #2 pencil
- Bring to midterm: **student ID and #2 pencil(s)**

Let's calculate factorials

- Mathematical definition

  0! := 1;

  n! := n * (n-1) * … * 1

  := n * (n-1)! if n > 0

Iterative factorial

Iterative definition:

See lec21-factorial-iterative.cpp

factorial(0) := 1;

factorial(n) := n*(n-1)*(n-2)*…*3*2*1;

```
int factorial(int n) {
  int fact;
  if (n==0)
    fact = 1;
  else
    for (fact=n; n > 1; n--)
       fact = fact * (n-1);
  return fact;
}
```

Computing Factorial Iteratively

factorial(4) = 4 * 3
= 12 * 2
= 24 * 1
= 24

```
factorial(0) = 1;
factorial(n) = n*(n-1)*…*2*1;
```

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Recursion

- A recursive definition includes a mention of itself
  - "My descendants are my children + all of my children's descendants."
  - "My keys are located in this room or in some other room."
- A recursive function includes [at least one] call to itself
  - Base case: when to stop (simplest case)
  - Recursive step: a general statement that reduces the task (eventually) to a base case

Recursive Factorial

See lec21-factorial-recursive.cpp

<u>Recursive</u> definition:

Base case: factorial(0) = 1;

Recursive step: factorial(n) = n*factorial(n-1);

```
int factorial(int n) {
   if (n == 0)  /* Base case */
     return 1;
   else
     /* recursive call */
     return n * factorial(n - 1);
}
```

Computing Factorial Recursively

factorial(4) = 4 * factorial(3)
= 4 * (3 * factorial(2))
= 4 * (3 * (2 * factorial(1)))
= 4 * (3 * (2 * (1 * factorial(0))))
= 4 * (3 * (2 * (1 *1)))
= 4 * (3 * (2 * 1))
= 4 * (3 * 2)
= 4 * 6
= 24

```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);
```

Differences

- Pros
  - Readability
- Cons
  - Efficiency
  - Memory

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Recursive Factorial

Stack

Executes factorial(4)

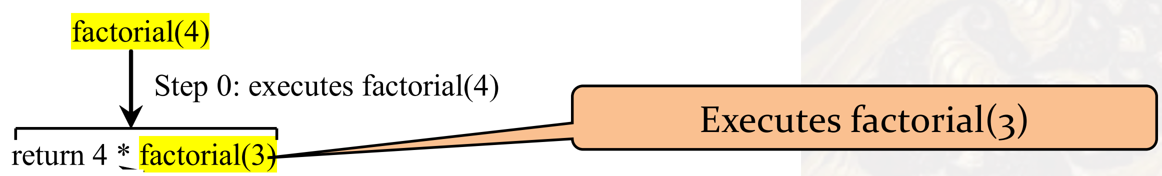
factorial(4)

Space for factorial(4)

Space for main()

Recursive Factorial

Stack



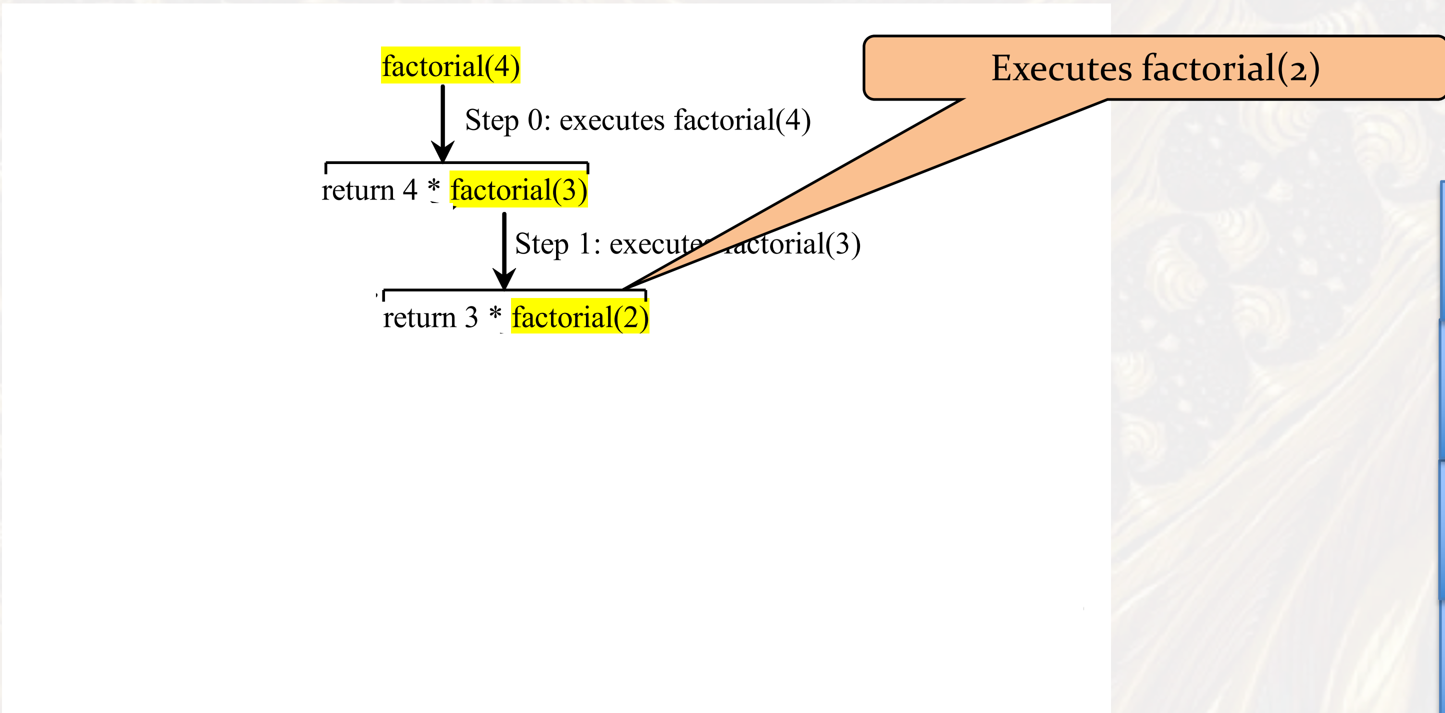
Space for factorial(3)

Space for factorial(4)

Space for main()

Recursive Factorial

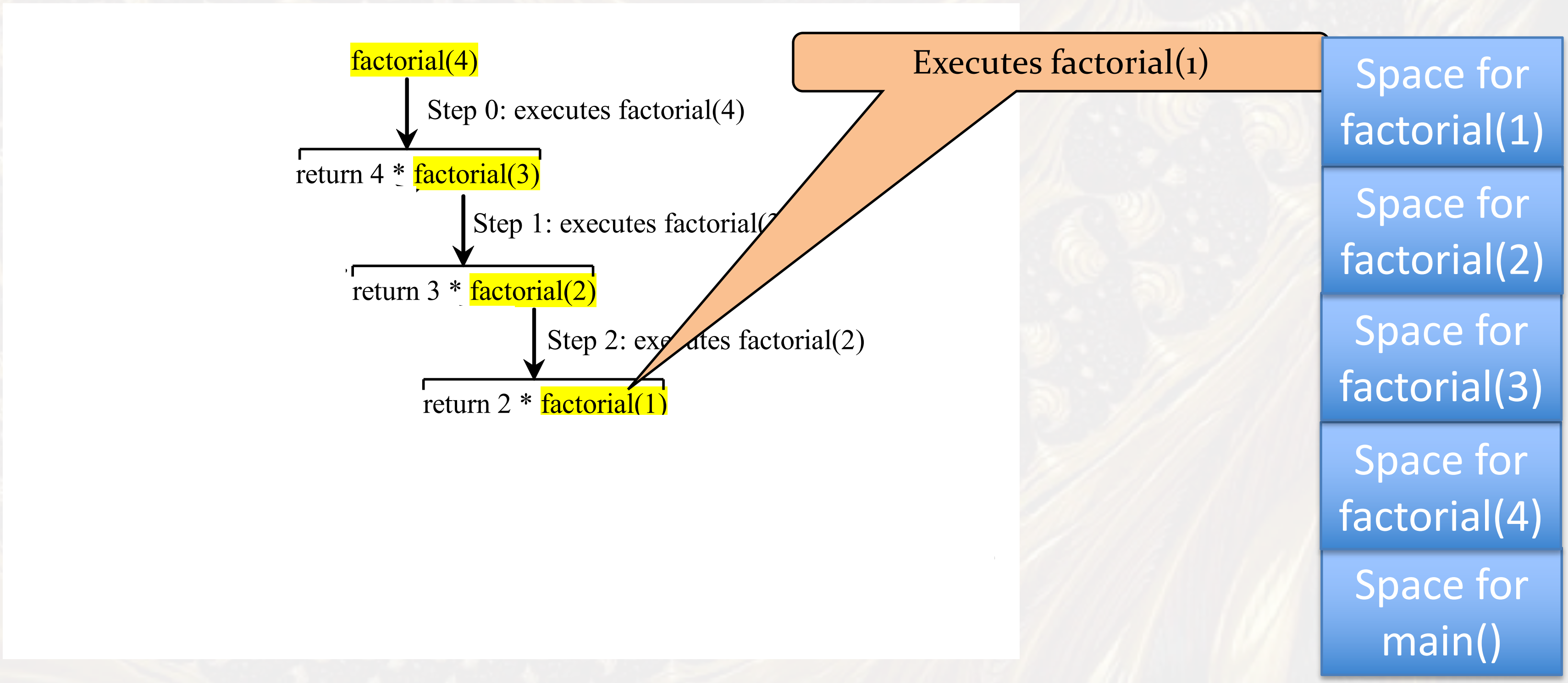
Stack



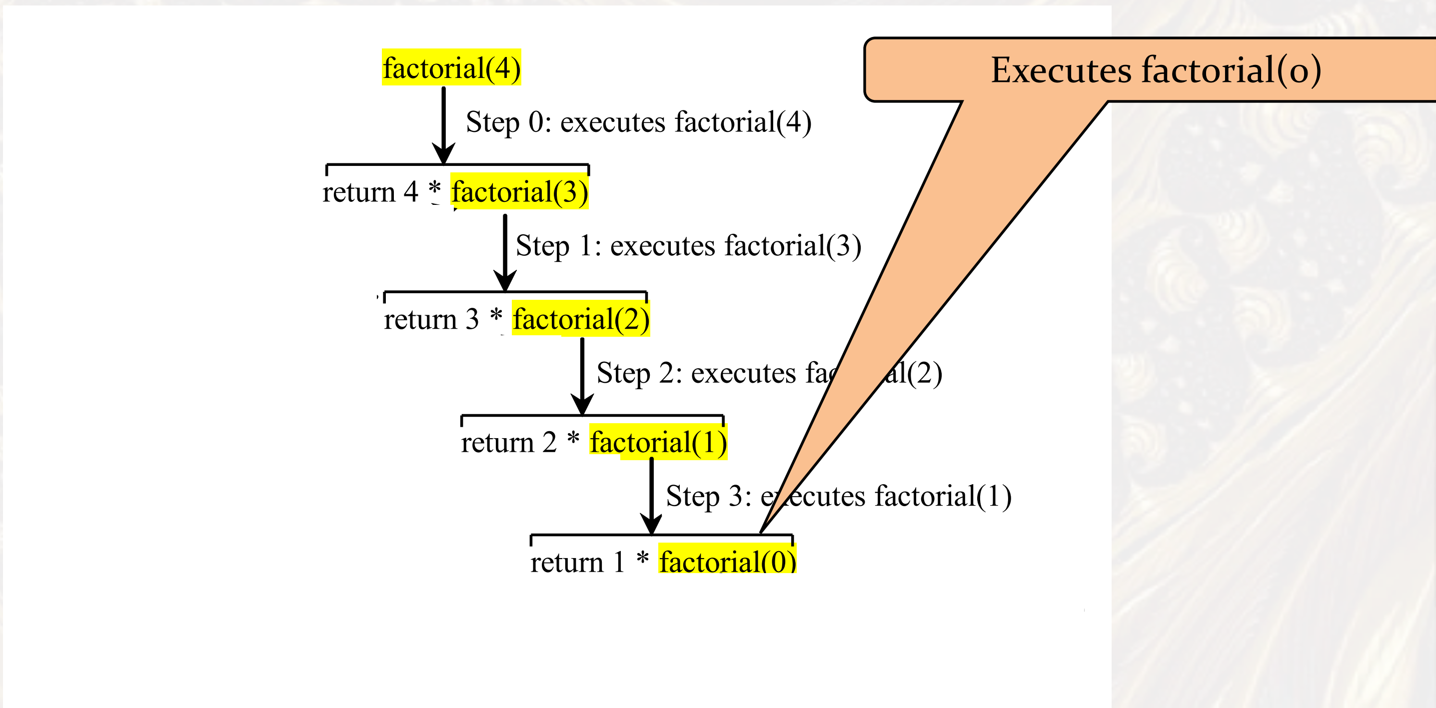
Space for factorial(2)
Space for factorial(3)
Space for factorial(4)
Space for main()

Recursive Factorial

Stack



Recursive Factorial

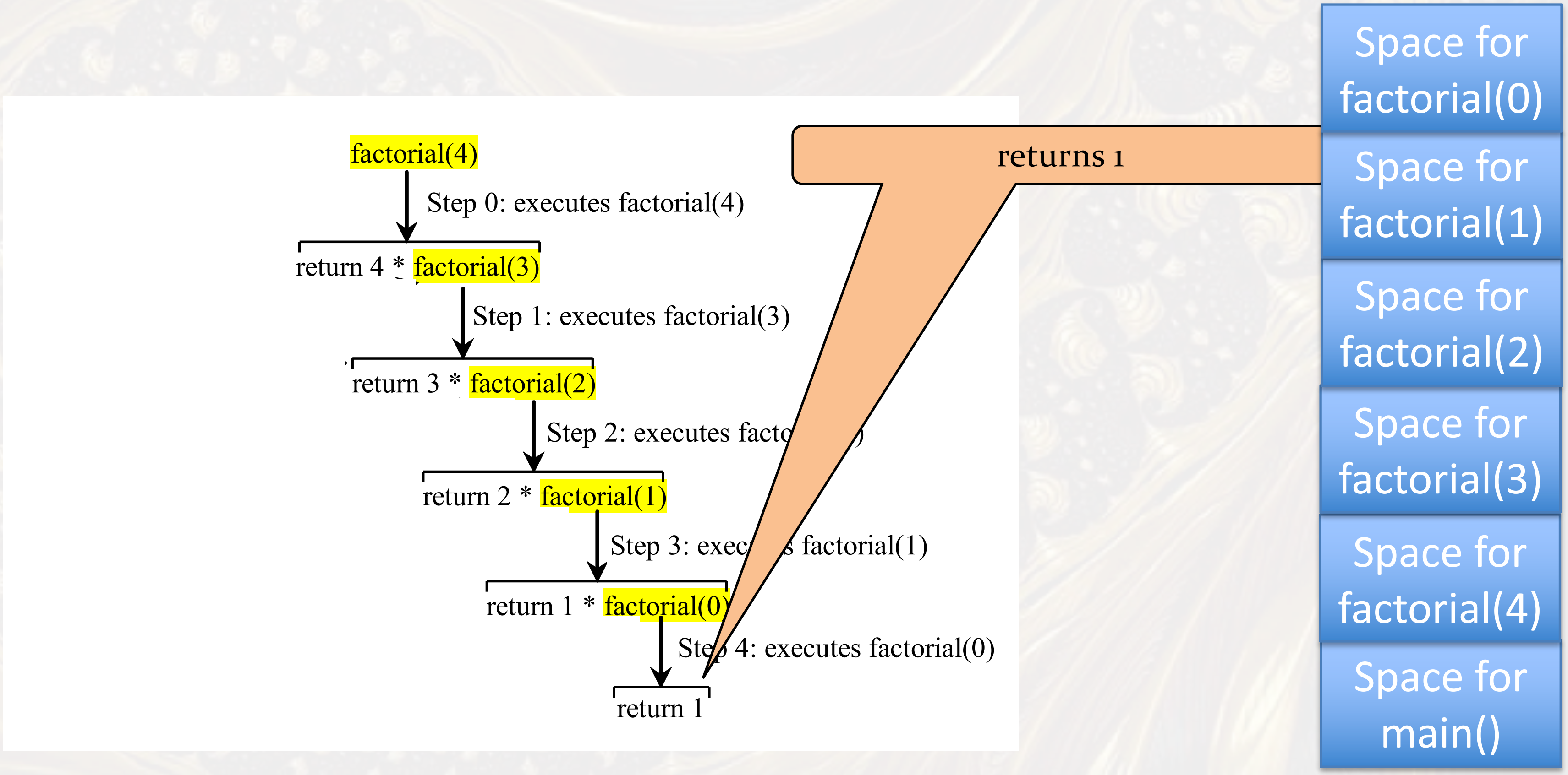


Stack

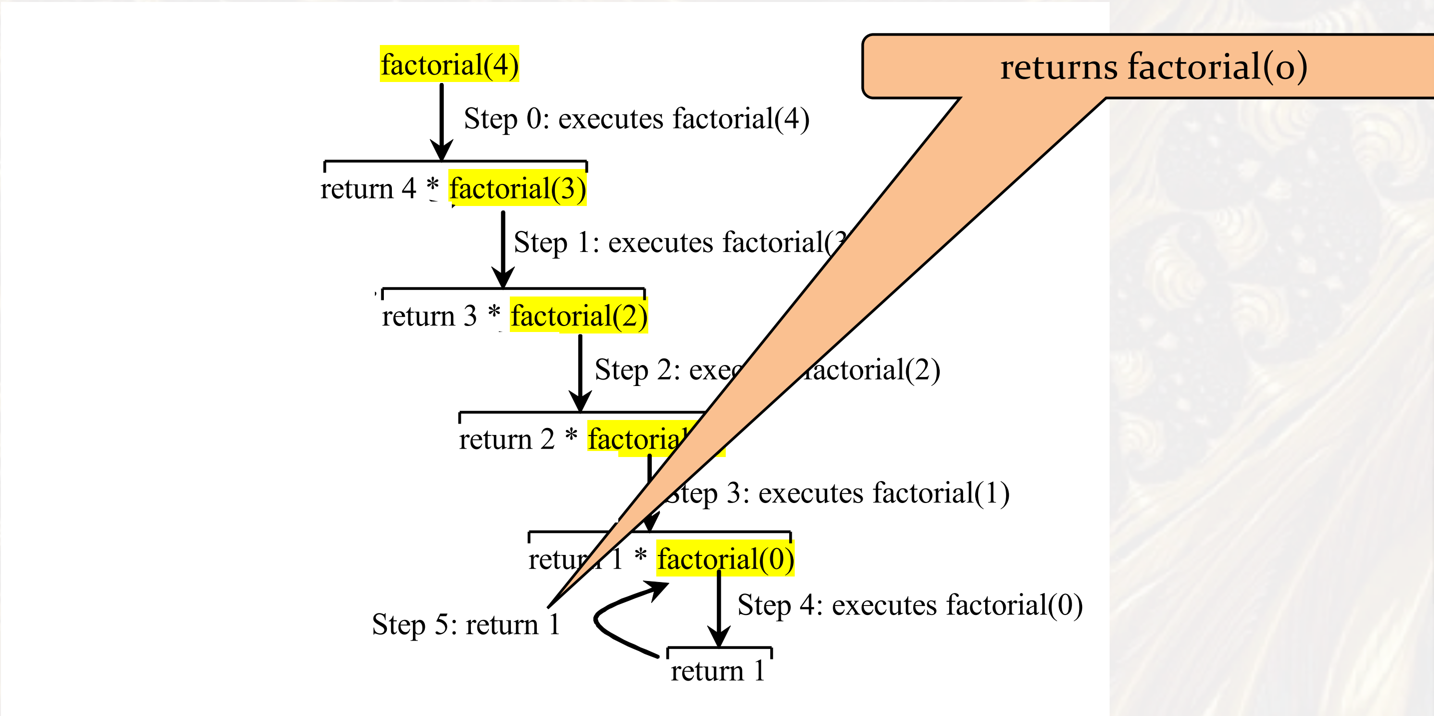
- Space for factorial(0)
- Space for factorial(1)
- Space for factorial(2)
- Space for factorial(3)
- Space for factorial(4)
- Space for main()

Recursive Factorial

Stack



Recursive Factorial



Stack

Recursive Factorial

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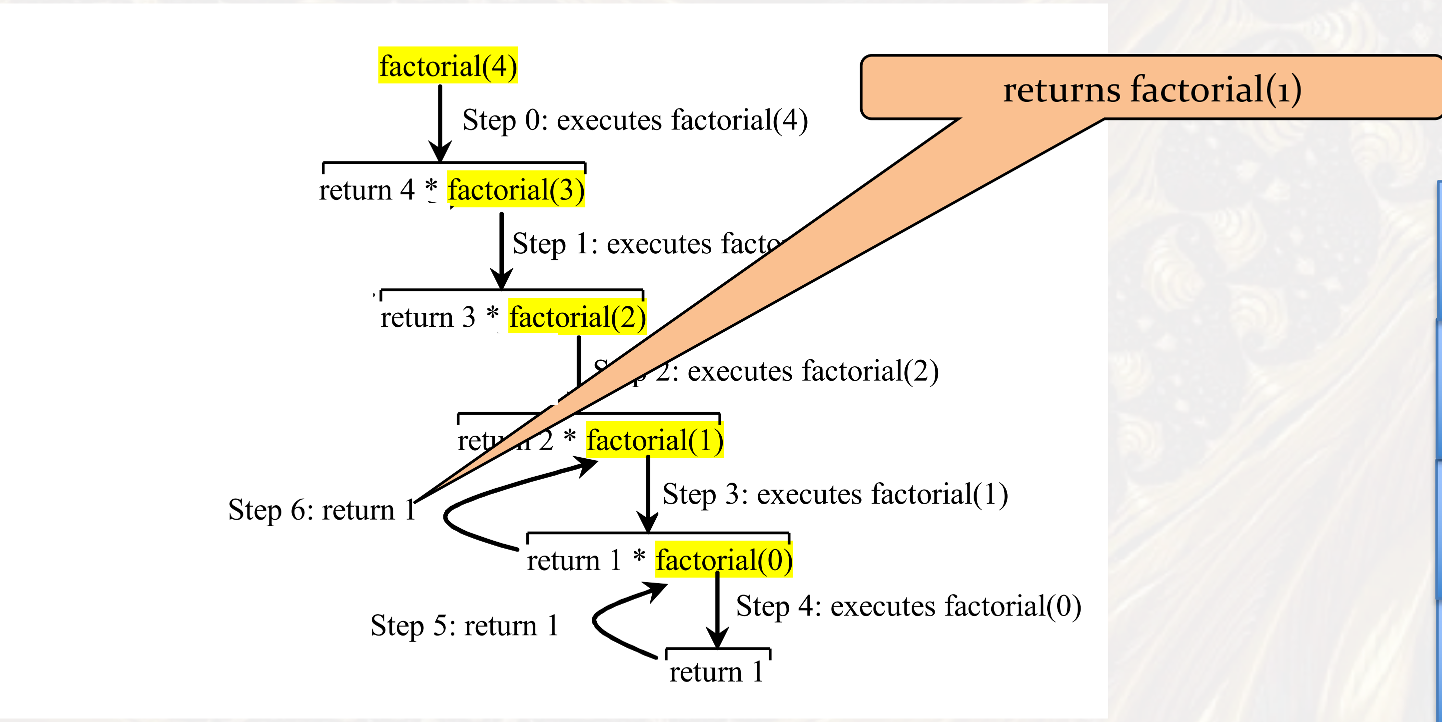
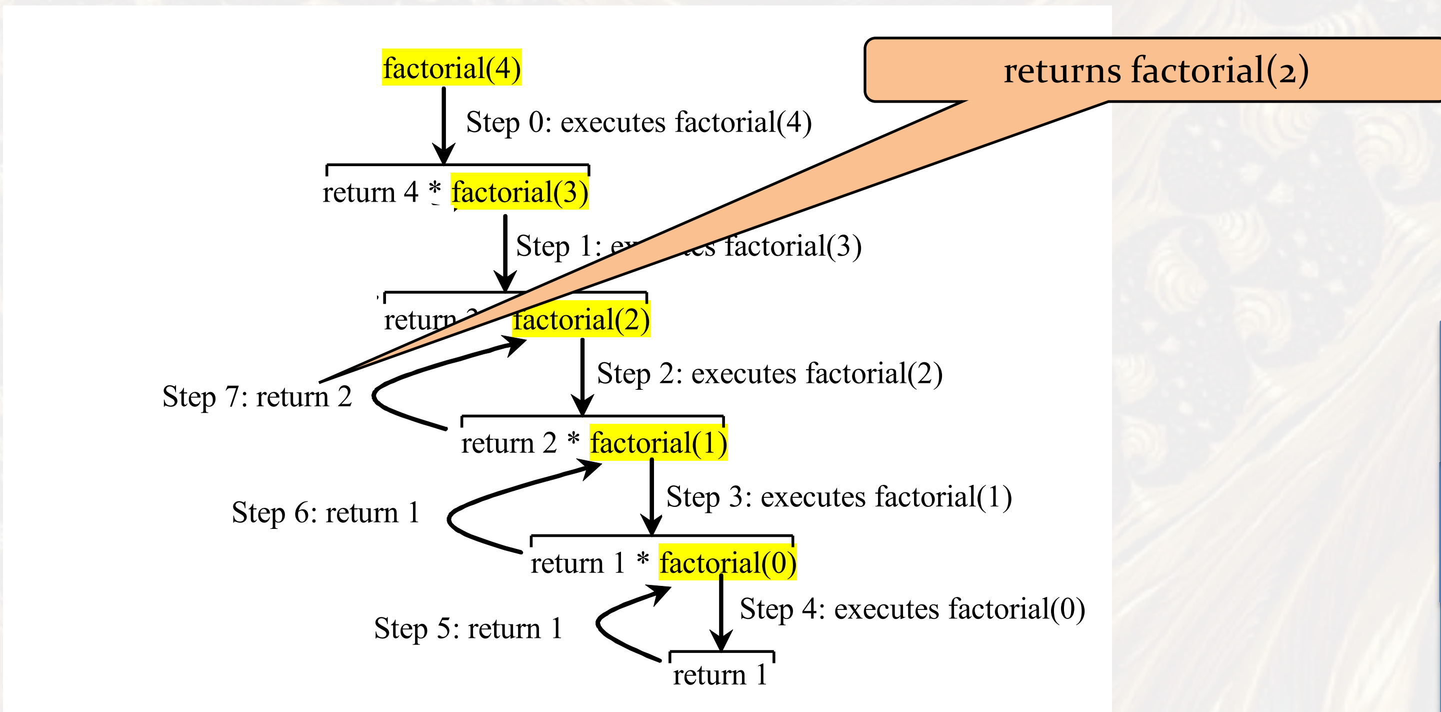
Stack



Space for factorial(2)
Space for factorial(3)
Space for factorial(4)
Space for main()

Recursive Factorial

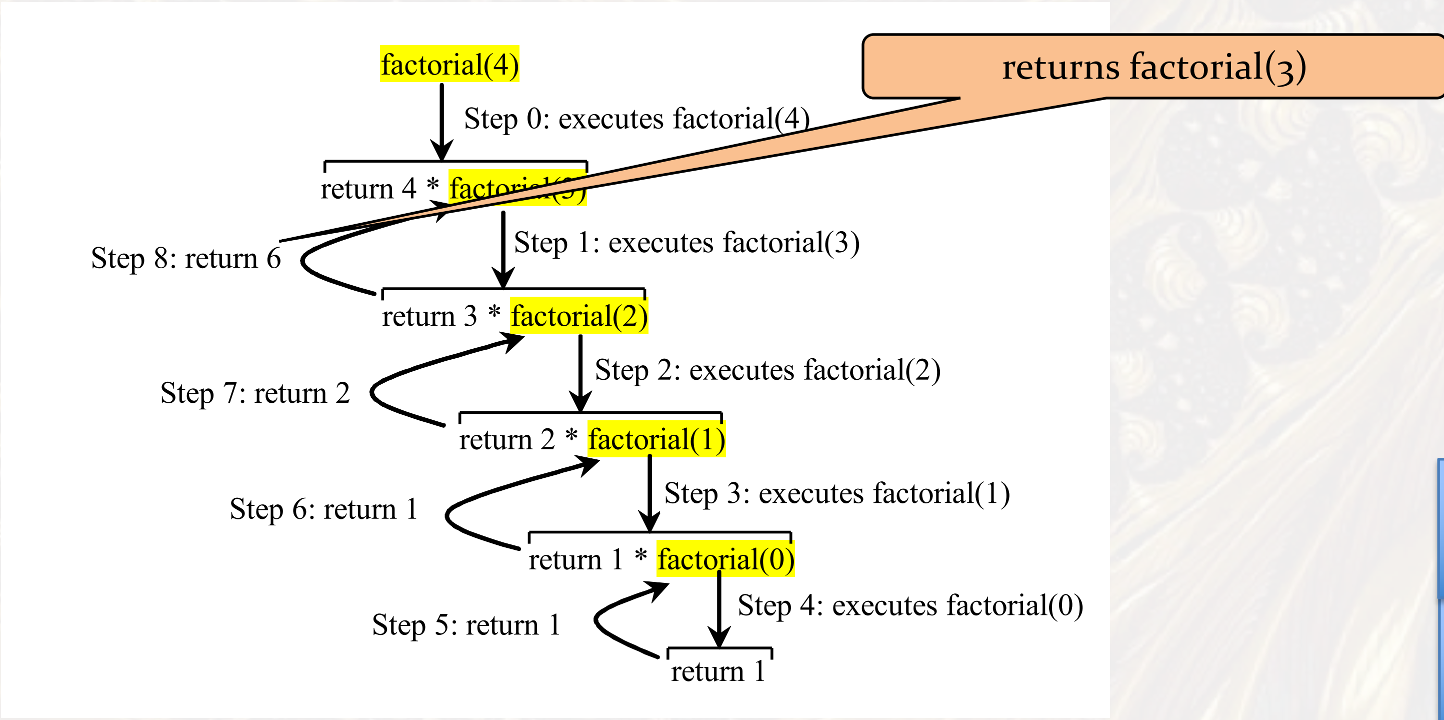


Stack

Space for factorial(3)
Space for factorial(4)
Space for main()

Recursive Factorial

Stack



Space for factorial(4)

Space for main()

Recursive Factorial

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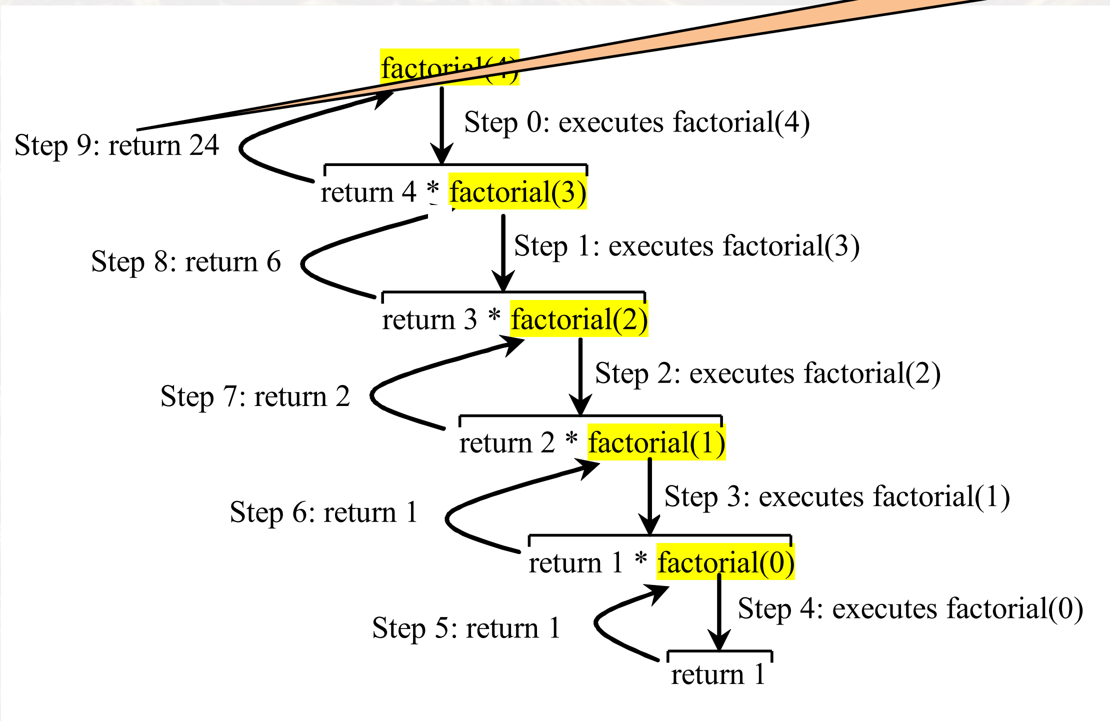
Stack

returns factorial(4)



Space for main()

When is recursion useful?

- Problems that have a "nested" or recursive structure and would be hard to write in an iterative fashion
  - Water in a river is the sum of the water from each tributary
- Recursion breaks the problem into one small step + "the rest of the solution"

Your turn: descendants

- "My number of descendants is my number of children + the sum of my children's descendants."
  - What is the base case?
  - What is the recursive step?

Your turn: descendants

- "My number of descendants is my number of children + the sum of my children's descendants."
  - What is the base case?
    - No children: #descendants = 0
  - What is the recursive step?
    - #descendants = #children + #descendants(child1) + #descendants(child2) + …
  - This would be quite difficult to do in an iterative way!

Your turn: exponents

- Compute **base^exp** in a recursive function
  - What is the function prototype?
  - What is the base case?
  - What is the recursive step?

Your turn: exponents

- Compute **base^exp** in a recursive function called pwr()
  - What is the function prototype?
    - `int pwr(int base, int exp);`
  - What is the base case?
  - What is the recursive step?

Your turn: exponents

- Compute **base^exp** in a recursive function called pwr()
  - What is the function prototype?
    - `int pwr(int base, int exp);`
  - What is the base case?
    - exp = 0: return 1
  - What is the recursive step?
    - exp > 0: return base * pwr(base, exp-1)

Exponent implementation

See lec21-power-recursive.cpp

```
int pwr(int base, int exp) {
  if (exp == 0) /* base case */
    return 1;
  else
    /* recursive call */
    return base * pwr(base, exp - 1);
}
```

Gotchas

- Failure to specify base case => stack overflow
- Failure to reach base case => stack overflow
  - Problem doesn't get smaller

```
int myfun(int n) {
  if (n == 0)
    return 0;
  else
    return myfun(n);
}
```

What vocabulary did we learn today?

- Recursion
- Base case
- Recursive step

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What ideas and skills did we learn today?

- How to design solutions with recursive definitions
- How to translate a recursive definition into a recursive function
- Merits of iteration versus recursion

Week 8 begins!

- ❑ Attend lab (laptop required)
- ❑ Read Rao lesson 7 (pp. 158-161)
  Read Miller lecture 8:
  http://www.doc.ic.ac.uk/~wjk/C++Intro/RobMillerL8.html
- ❑ Start on design for **Assignment 5** (due **Sunday, March 1**)

See you Wednesday (midterm review)!

- ❑ Bring your questions about material from weeks 1-7