Chapter 11: Recursion

Presentation slides for

Java Software Solutions

Foundations of Program Design

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by John Lewis and William Loftus

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Recursion

- Recursion is a fundamental programming technique that can provide an elegant solution certain kinds of problems

- Chapter 11 focuses on:
  - thinking in a recursive manner
  - programming in a recursive manner
  - the correct use of recursion
  - recursion examples

Recursive Thinking

- A *recursive definition* is one which uses the word or concept being defined in the definition itself

- When defining an English word, a recursive definition is often not helpful

- But in other situations, a recursive definition can be an appropriate way to express a concept

- Before applying recursion to programming, it is best to practice thinking recursively

Recursive Definitions

- Consider the following list of numbers:

```
24, 88, 40, 37
```

- Such a list can be defined as

```
A LIST is a:  number
       or a:  number  comma  LIST
```

- That is, a LIST is defined to be a single number, or a number followed by a comma followed by a LIST

- The concept of a LIST is used to define itself

Recursive Definitions

- The recursive part of the LIST definition is used several times, terminating with the non-recursive part:

```
number comma LIST
  24     ,   88, 40, 37

             number comma LIST
               88     ,   40, 37

                          number comma LIST
                            40     ,   37

                                       number
                                         37
```

Infinite Recursion

- All recursive definitions have to have a non-recursive part
- If they didn't, there would be no way to terminate the recursive path
- Such a definition would cause *infinite recursion*
- This problem is similar to an infinite loop, but the non-terminating "loop" is part of the definition itself
- The non-recursive part is often called the *base case*

Recursive Definitions

- N!, for any positive integer N, is defined to be the product of all integers between 1 and N inclusive

- This definition can be expressed recursively as:

```
1!  =  1
N!  =  N * (N-1)!
```

- The concept of the factorial is defined in terms of another factorial

- Eventually, the base case of 1! is reached

Recursive Definitions

```
        120
5!
              24
5 * 4!
                  6
    4 * 3!
                     2
        3 * 2!

            2 * 1!

                1
```

Recursive Programming

- **A method in Java can invoke itself; if set up that way, it is called a *recursive method***
- **The code of a recursive method must be structured to handle both the base case and the recursive case**
- **Each call to the method sets up a new execution environment, with new parameters and local variables**
- **As always, when the method completes, control returns to the method that invoked it (which may be an earlier invocation of itself)**

Recursive Programming

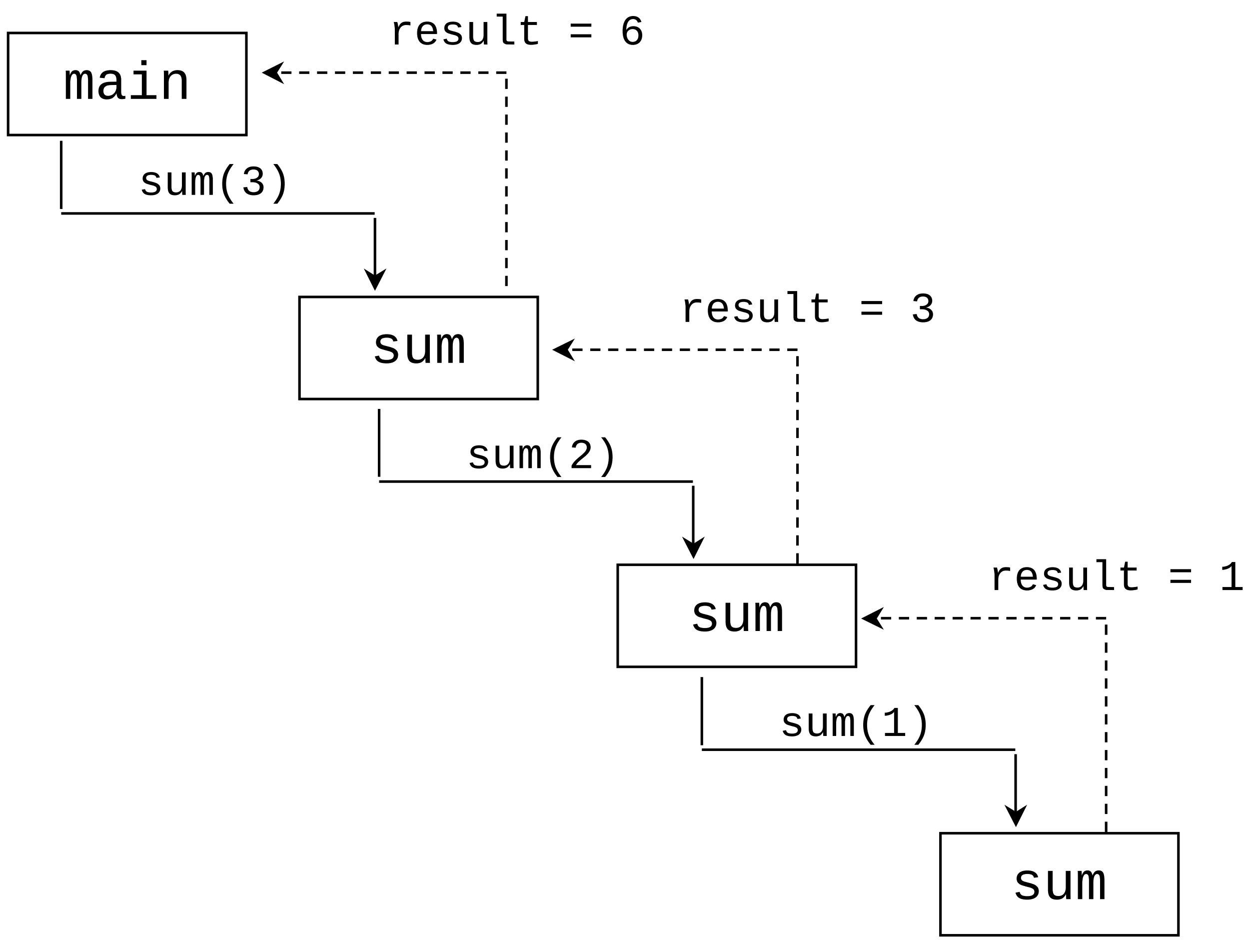
- Consider the problem of computing the sum of all the numbers between 1 and any positive integer N

- This problem can be recursively defined as:

$$\sum_{i=1}^{N} = N + \sum_{i=1}^{N-1} = N + (N-1) + \sum_{i=1}^{N-2}$$

$$= \text{etc.}$$

Recursive Programming



Recursive Programming

- Note that just because we can use recursion to solve a problem, doesn't mean we should

- For instance, we usually would not use recursion to solve the sum of 1 to N problem, because the iterative version is easier to understand

- However, for some problems, recursion provides an elegant solution, often cleaner than an iterative version

- You must carefully decide whether recursion is the correct technique for any problem

Indirect Recursion

- **A method invoking itself is considered to be *direct recursion***

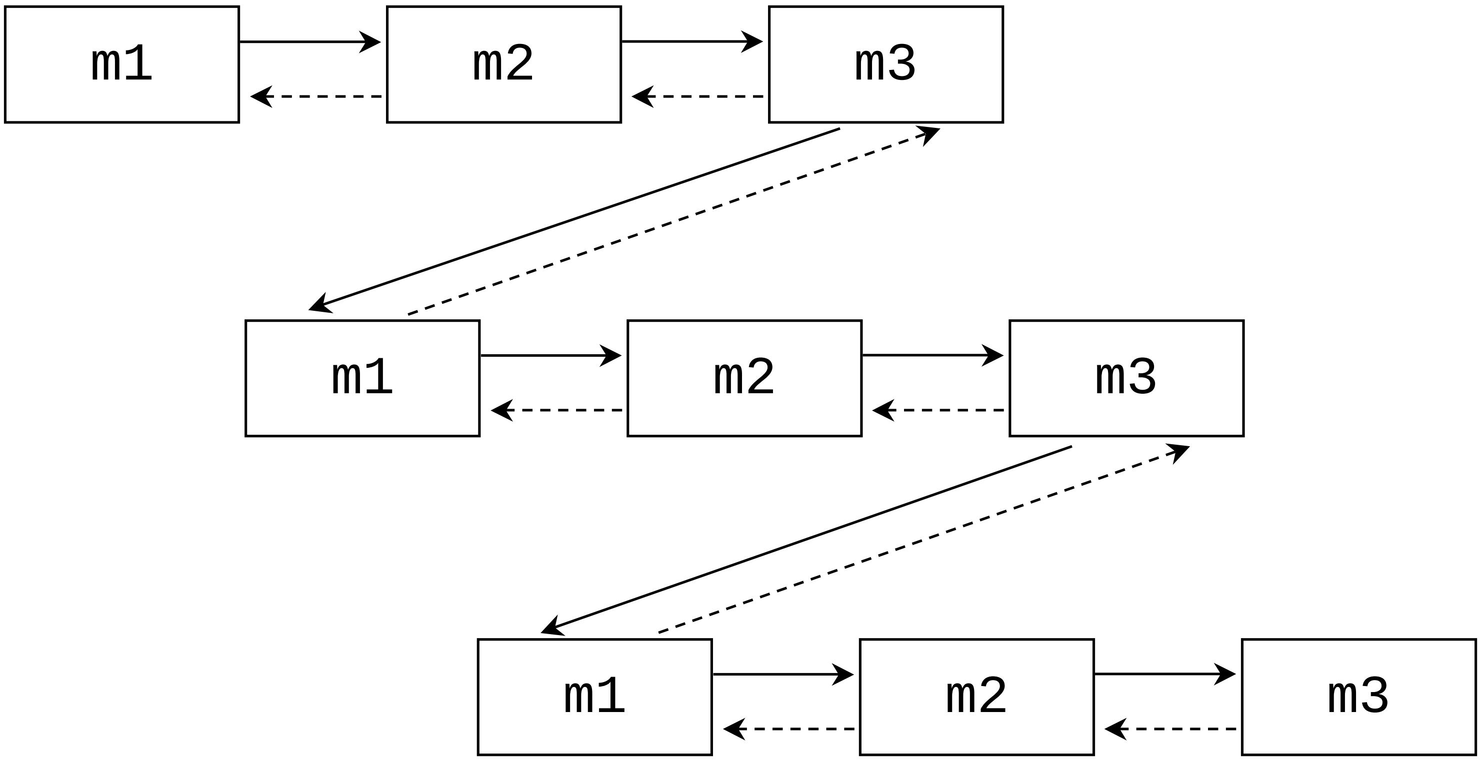
- **A method could invoke another method, which invokes another, etc., until eventually the original method is invoked again**

- **For example, method `m1` could invoke `m2`, which invokes `m3`, which in turn invokes `m1` again**

- **This is called *indirect recursion*, and requires all the same care as direct recursion**

- **It is often more difficult to trace and debug**

Indirect Recursion



Maze Traversal

- **We can use recursion to find a path through a maze**
- **From each location, we can search in each direction**
- **Recursion keeps track of the path through the maze**
- **The base case is an invalid move or reaching the final destination**
- **See `MazeSearch.java` (page 472)**
- **See `Maze.java` (page 474)**

Towers of Hanoi

- The *Towers of Hanoi* is a puzzle made up of three vertical pegs and several disks that slide on the pegs
- The disks are of varying size, initially placed on one peg with the largest disk on the bottom with increasingly smaller ones on top
- The goal is to move all of the disks from one peg to another under the following rules:
  - We can move only one disk at a time
  - We cannot move a larger disk on top of a smaller one

Towers of Hanoi

- **An iterative solution to the Towers of Hanoi is quite complex**
- **A recursive solution is much shorter and more elegant**
- **See `SolveTowers.java` (page 479)**
- **See `TowersOfHanoi.java` (page 480)**

Mirrored Pictures

- **Consider the task of repeatedly displaying a set of images in a mosaic that is reminiscent of looking in two mirrors reflecting each other**

- **The base case is reached when the area for the images shrinks to a certain size**

- **See `MirroredPictures.java` (page 483)**

Fractals

- **A *fractal* is a geometric shape made up of the same pattern repeated in different sizes and orientations**

- **The *Koch Snowflake* is a particular fractal that begins with an equilateral triangle**

- **To get a higher order of the fractal, the sides of the triangle are replaced with angled line segments**

- **See `KochSnowflake.java` (page 486)**
- **See `KochPanel.java` (page 489)**