Packages, enums, recursion & design

Lecture 14 of TDA 540 (Objektorienterad Programmering)

Carlo A. Furia Alex Gerdes

Chalmers University of Technology – Gothenburg University

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Packages

Packages provide a hierarchical naming mechanism for classes

- A package is a group of classes (and other packages)
- Packages can be nested inside other packages
- The package structure maps to the directory structure
  - one package per directory
  - one top-level public class (or interface) per file
- Unlike classes, packages are just a naming mechanism: you do not instantiate a package

```java
// file Car.java
package vehicles.cars;

public class Car
{ /* ... */ }
```

```java
// file Convertible.java
package vehicles.cars;

public class Convertible
  extends Car
{ /* ... */ }
class Sedan extends Car
{ /* ... */ }
```

Declaring packages

Writing `package P` at the beginning of a file `F.java` declares that the entities (classes, interfaces, etc.) in file `F.java` belong to package `P`.

- The fully qualified name of any entity `C` declared in file `F.java` is `P.C`
- The fully qualified name unambiguously identifies any top-level entity in a Java program
- A package `N` nested inside another package `P` is declared as `package P.N`
- If file `F.java` declares no package, its entities are part of an implicit anonymous package shared by all files in the same directory
  - It is good practice to declare a package explicitly for all programs but the simplest ones

Using packages

```java
// file Vehicle.java
package vehicles;
public interface Vehicle
{ /* ... */ }
```

```java
// file Car.java
package vehicles.cars;
import vehicles.*;

public class Car implements Vehicle
{ /* ... */ }
class Convertible extends Car
{ /* ... */ }
```

```java
// file Main.java
package retailer;
import vehicles.*;
// Vehicle imported by vehicles.*
Vehicle car, conv;
car = new vehicles.cars.Car();  // OK: fully-qualified name
// error: Convertible not visible here
conv = new Convertible();
```

Using packages

Writing `import P.C` makes entity `C` in package `P` available in the current file (as if it were declared here)

- If another entity also named `C` already exists in the importer's package, it shadows `P.C`
  - use the fully-qualified name to access `P.C`
- `import P.*` makes all entities in package `P` available, but not those in `P`'s subpackages.
- entities in system package `java.lang` are implicitly imported anywhere

```
package foo.bar.baz;
import java.util.Set;     // import interface Set from java.util
import java.awt.*;        // import all entities in java.awt
import java.awt.event.*; // import all entities in java.awt.event
```

Static imports

Writing `import static P.C.S` makes `static` entity `S` in class `P.C` available in the current file (as if it were declared here)

```
import static java.lang.Math.PI;  // π = 3.1415...
import static java.lang.Math.cos; // cos function
// ...
double len = cos(PI/2.0);
```

Guidelines for using packages

When importing from existing packages:

- use fully-qualified names if you only refer to an entity once or twice
- prefer fully-qualified names if traceability (where was this declared?) is important
- consider fully-qualified names to distinguish between entities with similar names in different packages
- use `import P.*` if you use several entities from the same package
- trade-off between clarity and readability

When declaring new packages:

- group coupled classes in the same package
- use packages in combination with default package visibility
- do not overuse hierarchical packages: packages should roughly be one order of magnitude fewer than classes

Core packages in Java

- `java.lang`: basic language functionality, fundamental types
- `java.util`: collection framework
- `java.io` and `java.nio`: old and new file input/output
- `java.math`: multi-precision arithmetic
- `java.net`: networking
- `java.security`: cryptography
- `java.sql`: database access
- `java.awt`: native GUI components
- `javax.swing`: platform-independent GUI components

Pop quiz!

1. Go to `kahoot.it`
2. Enter PIN shown on projector screen
3. Pick a nickname and go!

Enumerated types (enums)

Enumerated types are a convenient solution to create types with only a finite number of values.

- yes, no, I don't know
- Swedish counties: Stockholm, Uppsala, Kalmar, Västra Götaland, Dalarna, ...
- age ranges: infant, adolescent, adult, senior

```
enum Answer { YES, NO, DONT_KNOW };
```

Type `Answer` is a reference type that implicitly inherits from class `Enum` and includes 3 distinct constant values `Answer.YES`, `Answer.NO`, and `Answer.DONT_KNOW`.

Even if they are reference types, using `==` compares instances of **`enum`** types by value.

Enumerated types (enums)

Enumerated types are just a special syntax for classes with some restrictions. In particular, you can redefine how values are displayed and compared.

```
enum Answer {
  YES("Y"),
  NO("N"),
  DONT_KNOW("?");

  Answer(String repr)
  { this.repr = repr; }

  private String repr;

  @Override
  public String toString()
  { return this.repr; }
}
```

```
Answer a = Answer.YES;
System.out.println(a);  // print "Y"
```

Software design

Understanding the behavior of the various programming language constructs is only the first step towards writing good programs.

- good $\simeq$ correct, readable, modifiable, efficient, ...

We give an overview of some design principles and techniques that can help write better programs.

- Design techniques:
  - top-down design
  - bottom-up design
  - refactoring
  - test-driven development
- Design principles:
  - do not repeat yourself
  - keep it simple
  - information hiding
  - design for change

Top-down design

1. start designing the high-level (abstract) components (abstract classes and method signatures)
2. refine (reduce abstraction) the components by adding details
3. until everything is concrete and executable

Step 1:

```
interface AccountI {
  void deposit(int amount);
}
```

Step 2:

```
abstract class Account
  implements AccountI
{ int balance;

  // set balance to 0
  Account() { }

  // add 'amount' to 'balance'
  abstract
  void deposit(int amount);
}
```

Step 3:

```
class Account
  implements AccountI
{ int balance;

  // set balance to 0
  Account() { balance = 0; }

  // add 'amount' to 'balance'
  void deposit(int amount)
  { balance += amount; }
}
```

Top-down design

Top-down design is also applicable at the level of individual method implementations as stepwise refinement.

Step 1:

```
// input: non-null array a
// output: sum of values in a
int sum(int[] a)
{  }
```

Step 2:

```
// input: non-null array a
// output: sum of values in a
int sum(int[] a)
{ int sum = 0;
  // for each position k in a:
  // add a[k] to sum
  return sum;  }
```

Step 3:

```
// input: non-null array a
// output: sum of values in a
int sum(int[] a)
{ int sum = 0;
  // for each position k in a:
  // add a[k] to sum:
  sum += a[k];
  return sum;  }
```

Step 4:

```
// input: non-null array a
// output: sum of values in a
int sum(int[] a) {
{ int sum = 0;
  // for each position k in a:
  for (int k=0; k < a.length; k++)
  { // add a[k] to sum:
    sum += a[k]; }
  return sum;  }
```

Bottom-up design

1. start designing individual components independently, or reuse those provided by libraries
2. combine the components to build more complex components
3. until the overall functionality is implemented

Step 1:

```
class Account
{ /* ... */ }

class Person
{ /* ... */ }


// Collections Framework
interface List<E>
{ /* ... */ }
class ArrayList<E>
{ /* ... */ }
```

Step 2:

```
class PersonalAccount
  extends Account
{
  Person owner;
  // ...
}
```

Step 3:

```
class Bank
{
  final float interest = 0.02;

  ArrayList<PersonalAccount> accounts;

  void depositInterest()
  {
    for (a : accounts)
      a.deposit(a.balance * interest);
  }
  // ...
}
```

Top-down and bottom-up

Object-oriented programming languages support both top-down and bottom-up development:

- top-down: inheritance, abstract classes, interfaces
- bottom-up: encapsulation, polymorphism, assertions & exceptions

In practice programs are often developed with a combination of top-down and bottom-up, with a mixture that depends on the specific problem being targeted.

Refactoring

Any realistic software development process goes through trials and errors: you hardly ever get the program right at the first attempt!

Refactoring is the activity of changing parts of the design or implementation of a program under development to improve and adapt it.

Examples of refactoring:

- introduce constants
- extract common implementations in two or more methods
- change the public interface of a class
- change the inheritance hiearchy
- ...

Refactoring: method extraction example

Before refactoring:

```
void deposit(int amount)
{ if (amount > 0)
    balance += amount; }

void withdraw(int amount)
{ if (amount > 0)
    balance -= amount; }
```

After refactoring:

```
void deposit(int amount)
{ if (isPositive(amount))
    addAmount(amount); }

void withdraw(int amount)
{ if (isPositive(amount))
    addAmount(-amount); }

private boolean isPositive(int amount)
{ return amount > 0; }

private void addAmount(int amount)
{ balance += amount; }
```

Test-driven development

In a previous class, we already emphasized the importance of writing tests. Test-driven development revolves around this principle:

- test extensively
- test early
- test often
- refactor implementation and tests accordingly

Test-drive development is often advocated with aggressive refactoring.

Design principles

Do not repeat yourself

- use constants
- refactor methods
- use libraries

Keep it simple

- refactor methods and classes
- use inheritance to gradually extend public interfaces
- use expressive constructs (e.g. exceptions) when appropriate

Information hiding

- use visibility modifiers appropriately
- public interfaces vs. private implementation details
- use abstract classes and interfaces

Design for change

- use genericity
- generalize (abstract) beyond the specific example
- but do not overdo it!

Recursion in programming

Recursion is a style of programming where methods are defined in terms of themselves.

The definition of a method `m` is recursive if the implementation of `m` includes a call to `m` (directly or indirectly).

```
// compute x^y, for y ≥ 0
int pow(int x, int y) {
  if (y == 0)
    return 1;
  else
    return x * pow(x, y - 1);
}
```

↑ recursive call

Recursion in mathematics

Recursion is a style of definition where concepts are defined in terms of themselves.

The definition of a concept is recursive if
it defines the concept in terms of an instance of the concept itself.

Definition of natural numbers:

- 0 is a natural number
- if n is a natural number then $n + 1$ is a natural number.

↑

recursive/inductive definition

Recursion: from math to programming

Recursion in programming provides a natural way of implementing recursive definitions in mathematics.

Factorial of a nonnegative integer n:

$$n! \triangleq \underbrace{n \cdot (n-1) \cdot \cdots \cdot 1}_{n \text{ terms}}$$

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$$n! \triangleq \begin{cases} 1 & \text{if } 0 \leq n \leq 1 \leftarrow \text{base case} \\ n \cdot (n-1)! & \text{if } n > 1 \leftarrow \text{recursive/inductive case} \end{cases}$$

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```
int factorial(int n) {
  if (n <= 1)
    return 1;                    // base case
  else
    return n * factorial(n - 1); // recursive case
}
```

recursive call

How does recursion work?

- Each recursive call runs an independent instance of the recursive method. (Independent means that it has its own private copy of actual arguments and local variables.)
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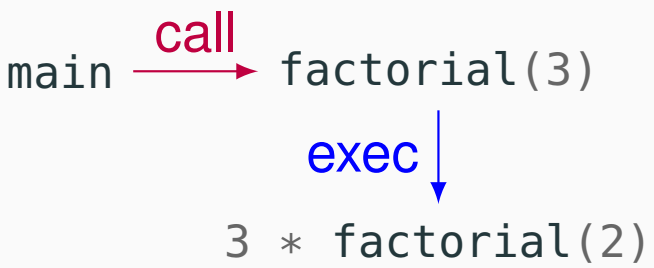

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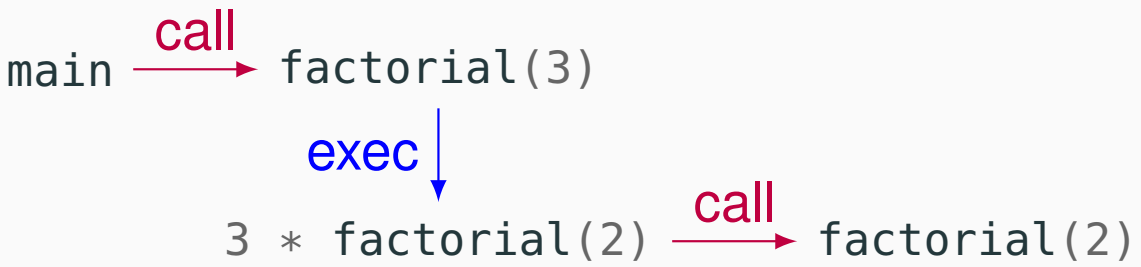

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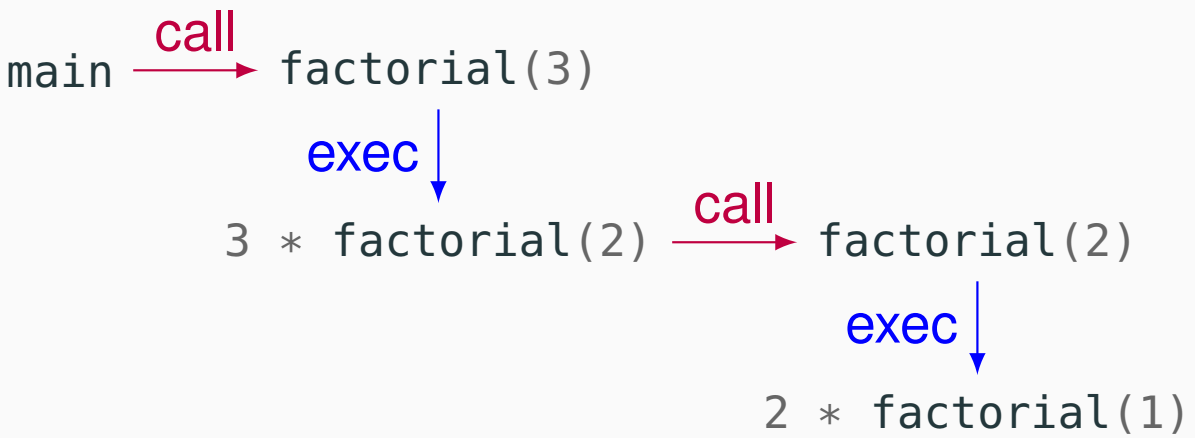

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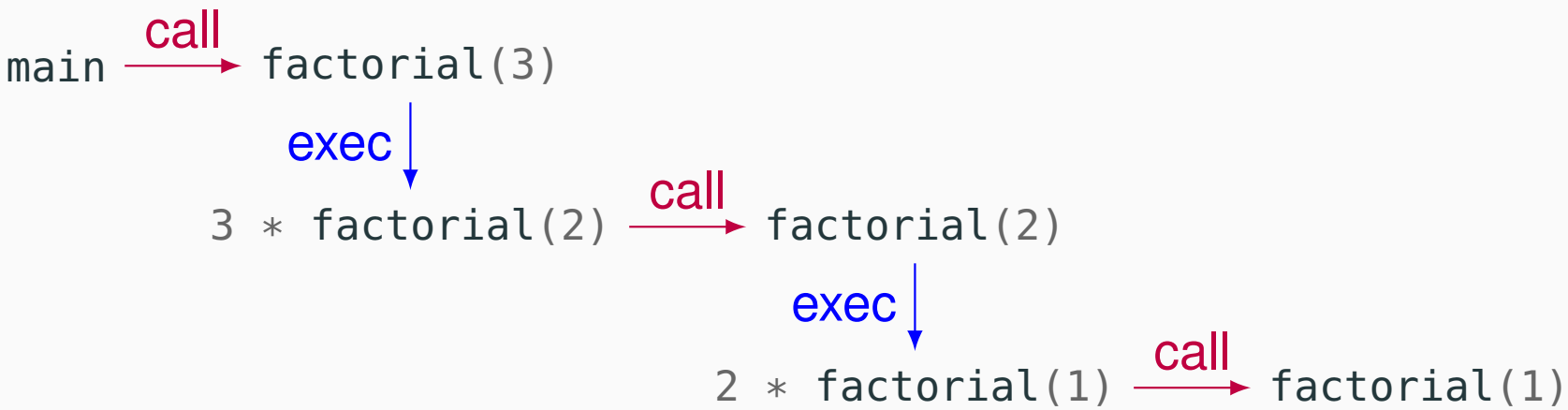

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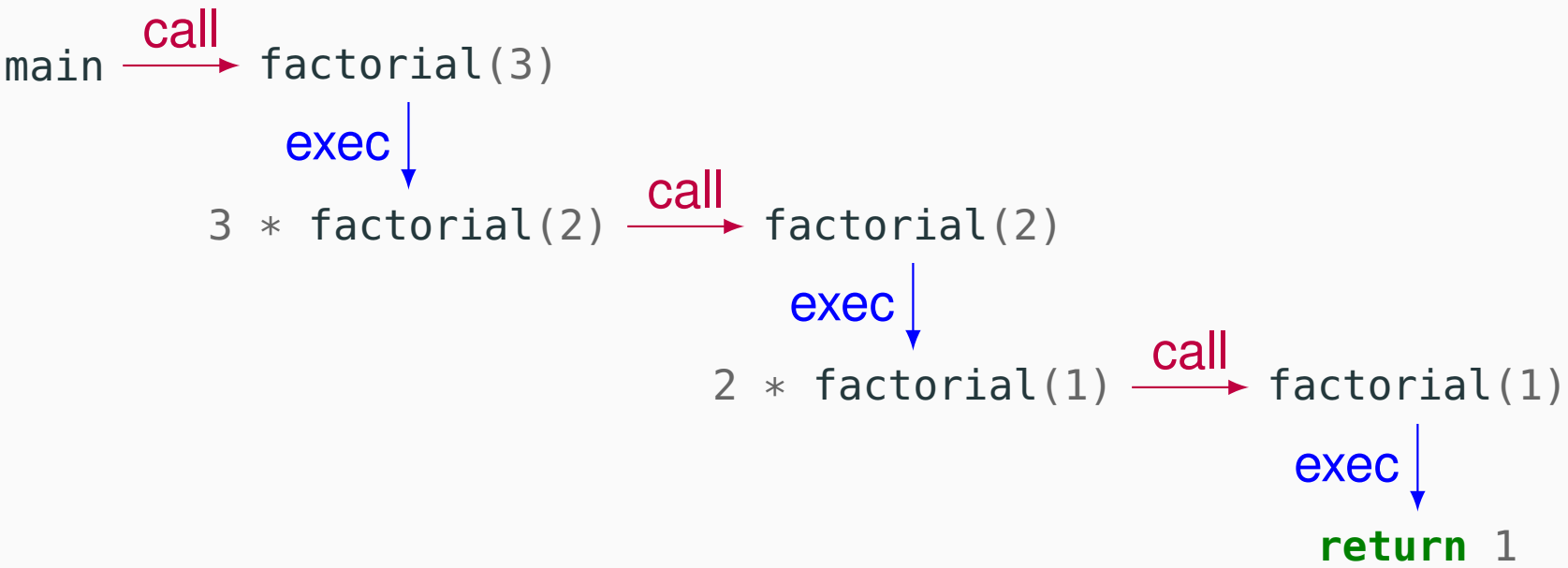

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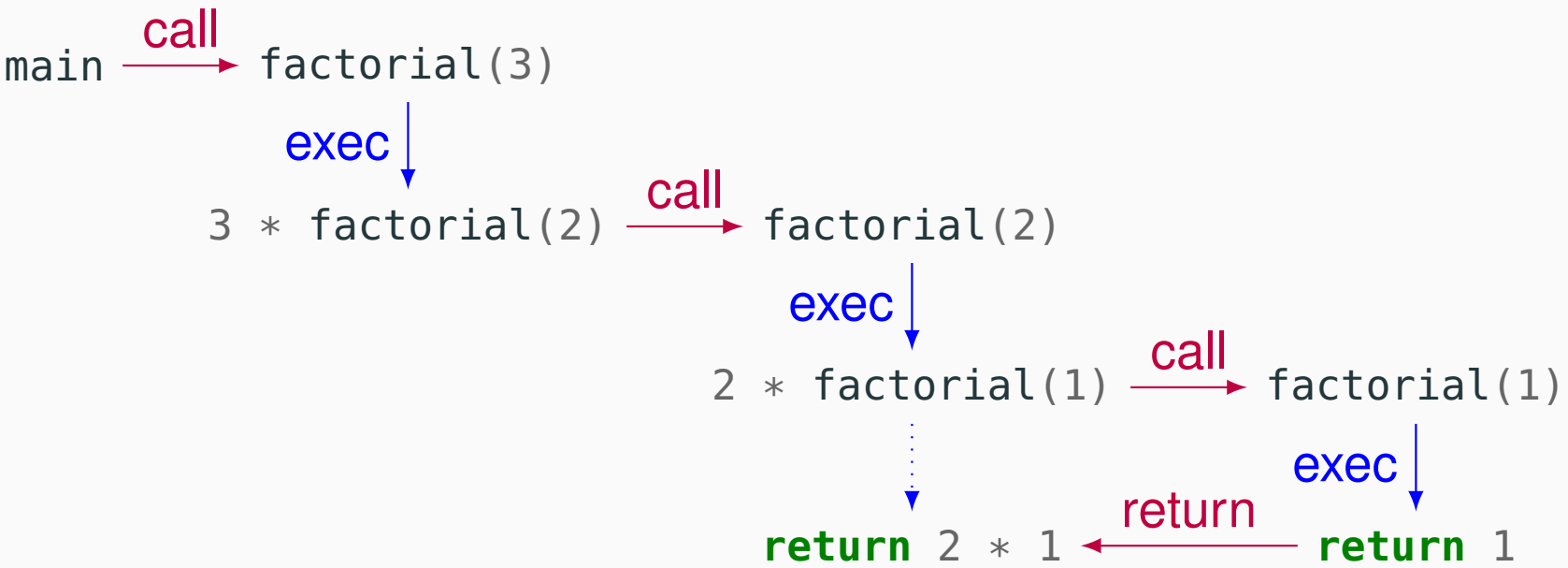

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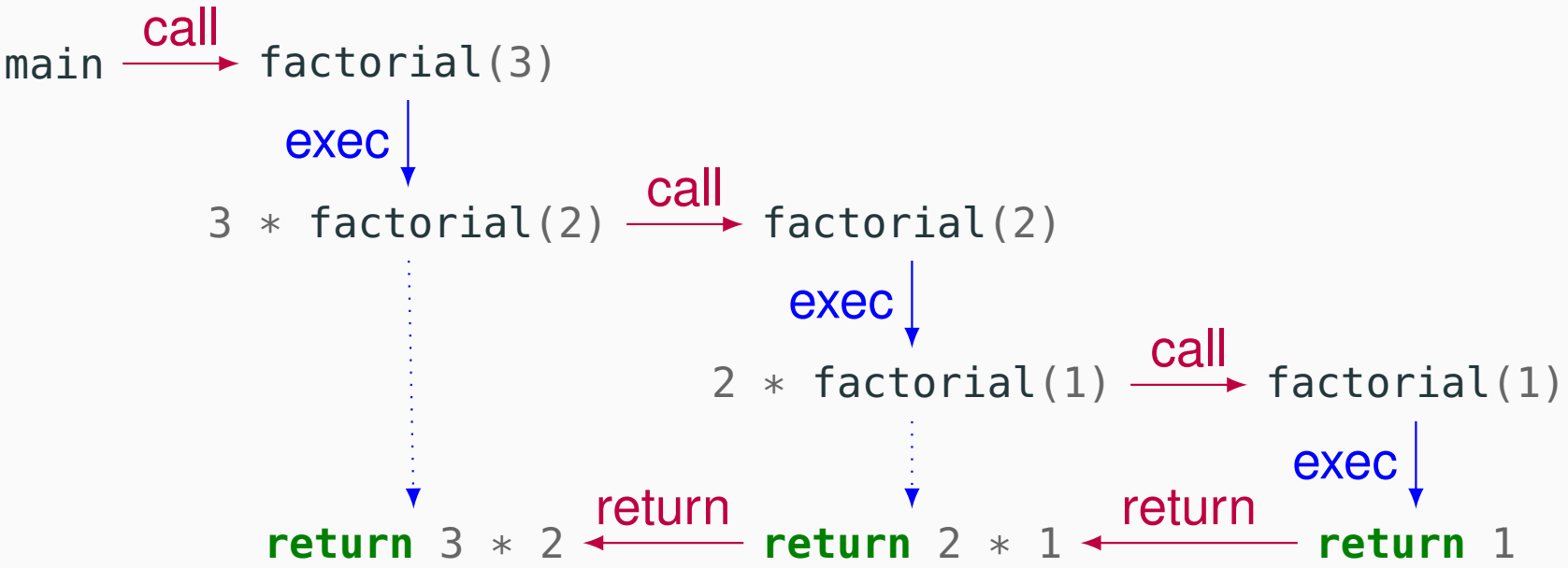

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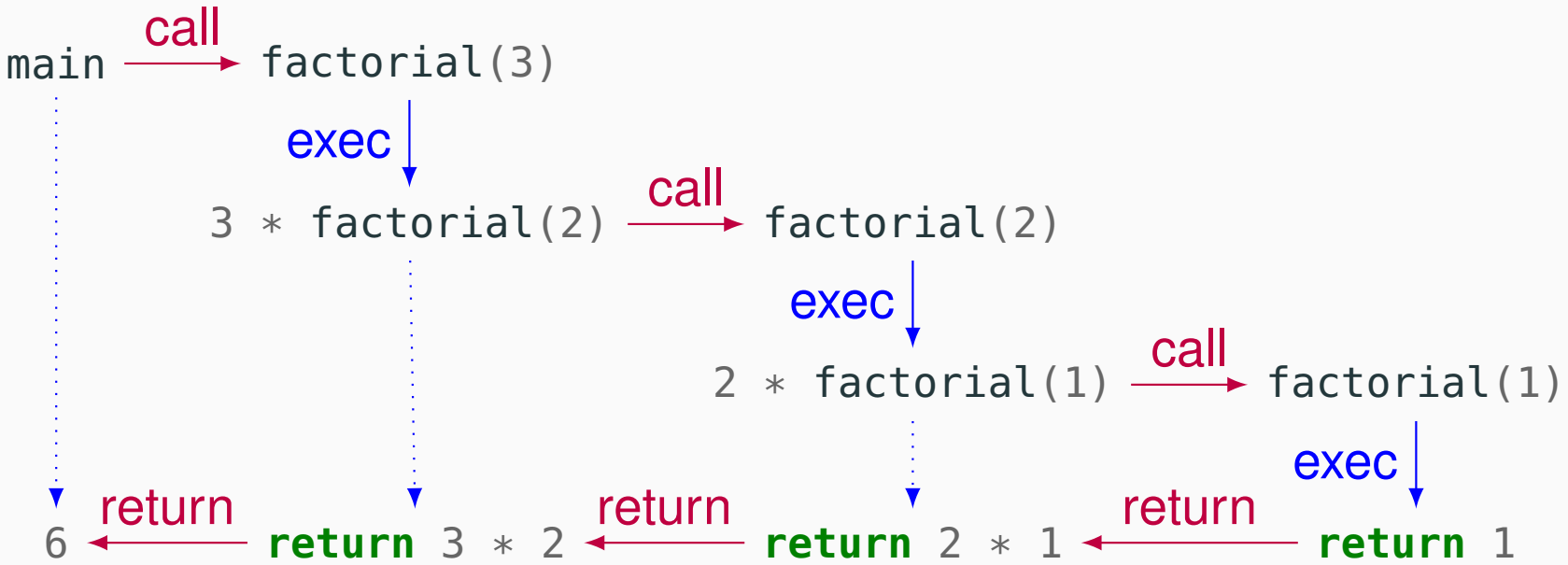


Recursion as a design technique

Recursion as a programming technique is useful to design programs using the divide and conquer approach:

To solve a problem instance P, split P into problem instances $P_1, \ldots, P_n$ chosen such that:

1. Solving $P_1, \ldots, P_n$ is simpler than solving P directly
2. The solution to P is a simple combination of the solutions to $P_1, \ldots, P_n$

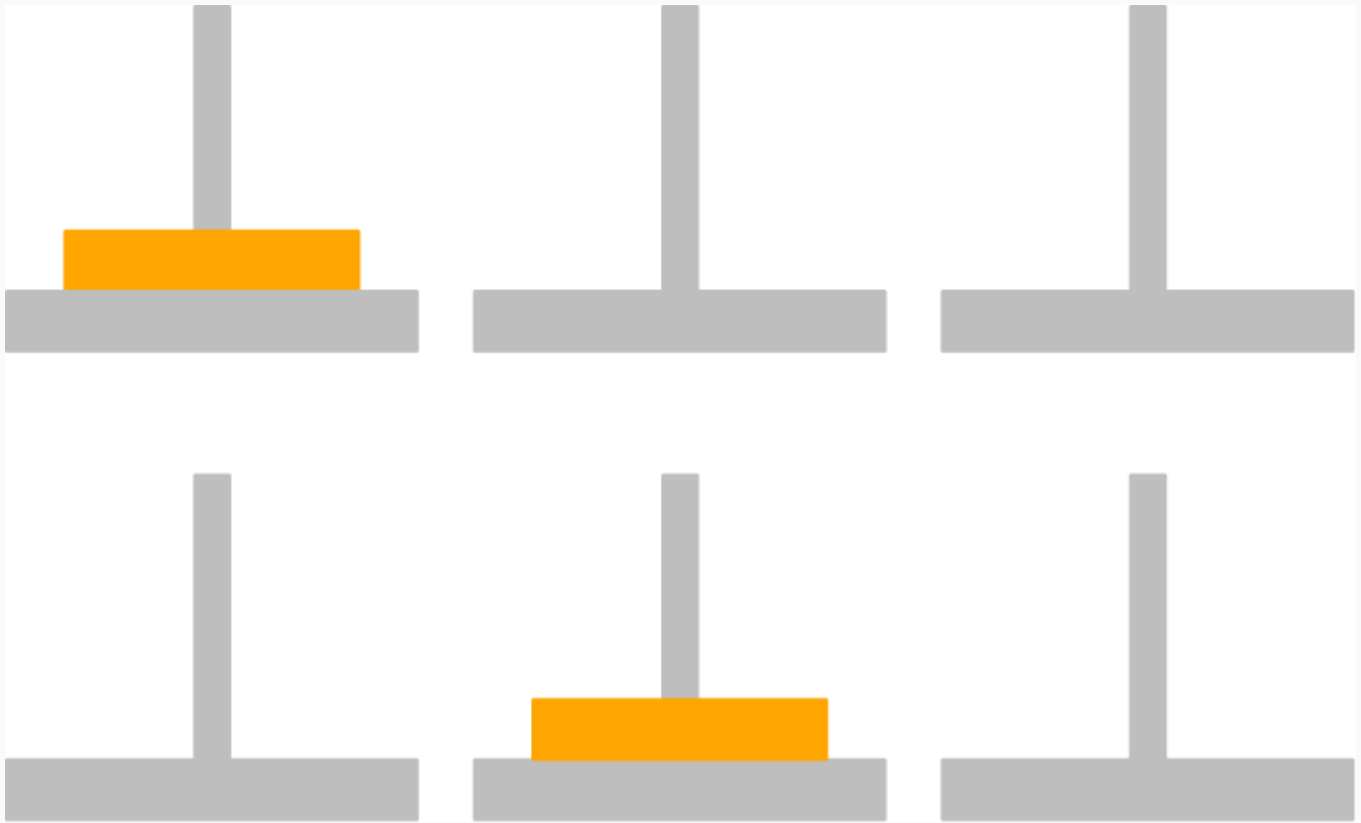
The Tower of Hanoi

Goal: move sorted stack of disks to from the left to the middle peg

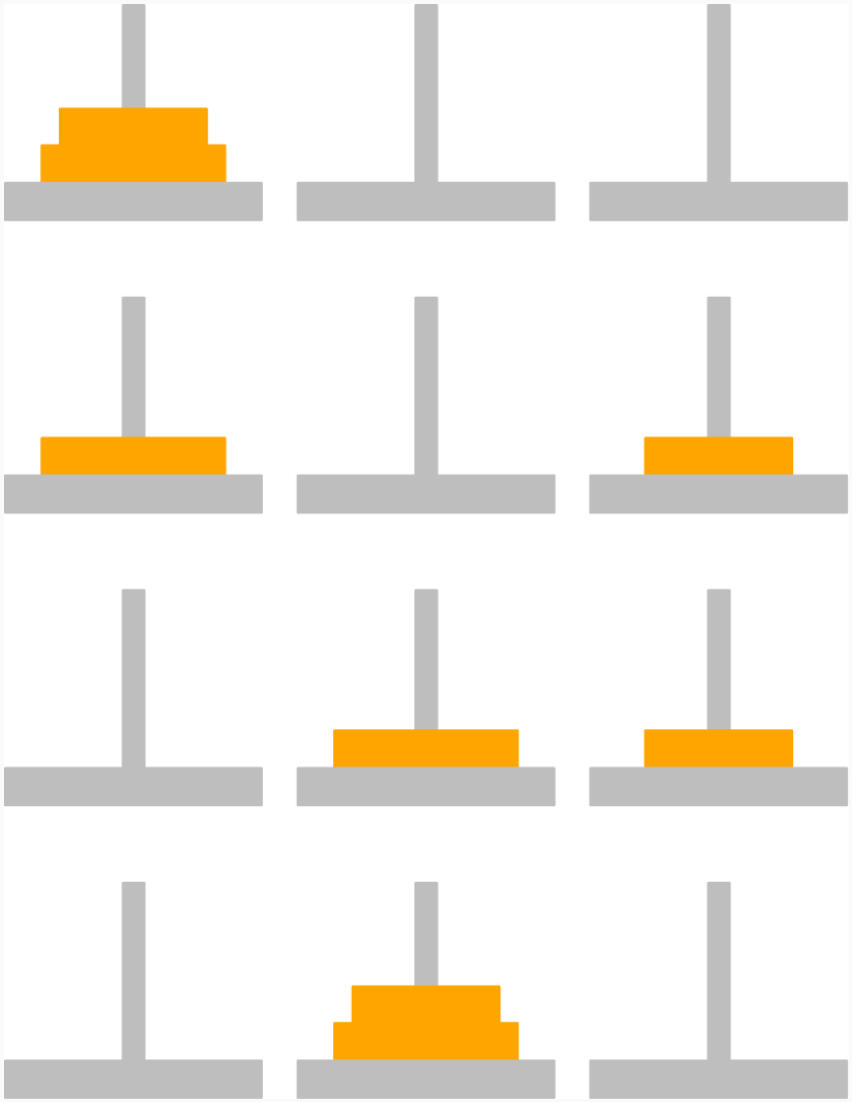
Rules:

1. Move one disk at a time
2. A move consists of taking the disk on top of one peg and placing it on top of another peg
3. Throughout the game, a larger disk can never be placed on top of a smaller disk

The Tower of Hanoi: one disk

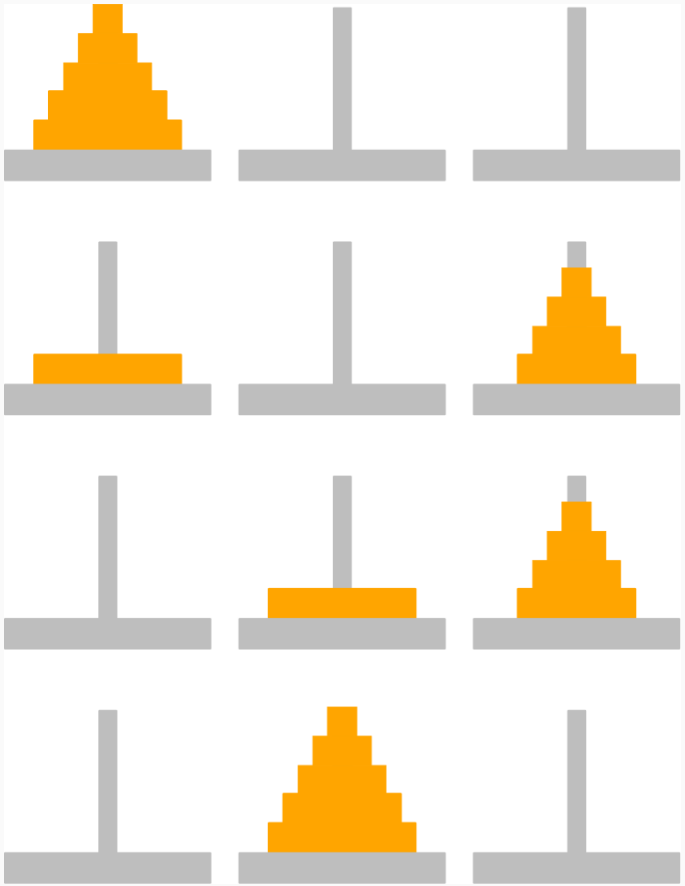


The Tower of Hanoi: two disks



The Tower of Hanoi: n disks

1. Recursively move $n - 1$ disks on a spare peg
2. Move remaining largest disk to destination peg
3. Recursively move $n - 1$ disks from spare peg to destination peg



The Tower of Hanoi: *n* disks

```
// move ‘n’ top disks
// from ‘source’ peg to ‘destination’ peg via ‘spare’ peg
public void move(int n,
  PegPosition source, PegPosition destination, PegPosition spare) {
  if (n == 1)
    // base case
    move(source, destination);
  else {
    // recursively move n - 1 to spare
    move(n - 1, source, spare, destination);
    // move largest disk to destination
    move(1, source, destination, spare);
    // recursively move n - 1 to destination
    move(n - 1, spare, destination, source);
  }
}
```

The original Tower of Hanoi

In the great temple of Benares, under the dome that marks the center of the world, three diamond needles, a foot and a half high, stand on a copper base. God on creation strung 64 plates of pure gold on one of the needles, the largest plate at the bottom and the others ever smaller on top of each other. That is the tower of Brahma. The monks must continuously move the plates until they will be set in the same configuration on another needle. The rule of Brahma is simple: only one plate at a time, and never a larger plate on a smaller one. When they reach that goal, the world will crumble into dust and disappear.

Édouard Lucas, *Récréations mathématiques*, 1883.

Got time for 64 disks?

- For n disks, the recursive solution generated by our program enumerates $2^n - 1$ moves
- We could show that this is the minimum number of moves to solve the problem following the rules
- If one move takes 1 millisecond, $2^{64} - 1$ milliseconds is about 580 million years
- For comparison: dinosaurs got extinct about 65 million years ago, humans are about 2.5 million years old

Bottom line: recursion is a powerful abstraction tool, which can be very effective at expressing the solutions to complex problems in a simple way.

Recursion vs. Iteration

In principle, anything that can be done using recursion can be done using iteration (loops) as well, and vice versa.

Recursive factorial:

```
int factorial(int n) {
  if (n <= 1)
    return 1;
  else
    return n * factorial(n - 1);
}
```

Iterative factorial:

```
int factorial(int n) {
  int factorial = 1;
  for (int k = n; k > 1; k--)
    factorial *= k;
  return factorial;
}
```

However, when the divide and conquer approach is naturally applicable, recursion often leads to more readable and clearer programs.