COMP1730/COMP6730
Programming for Scientists

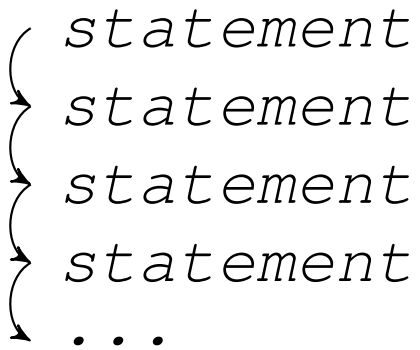
Control, part 1: Branching

Outline

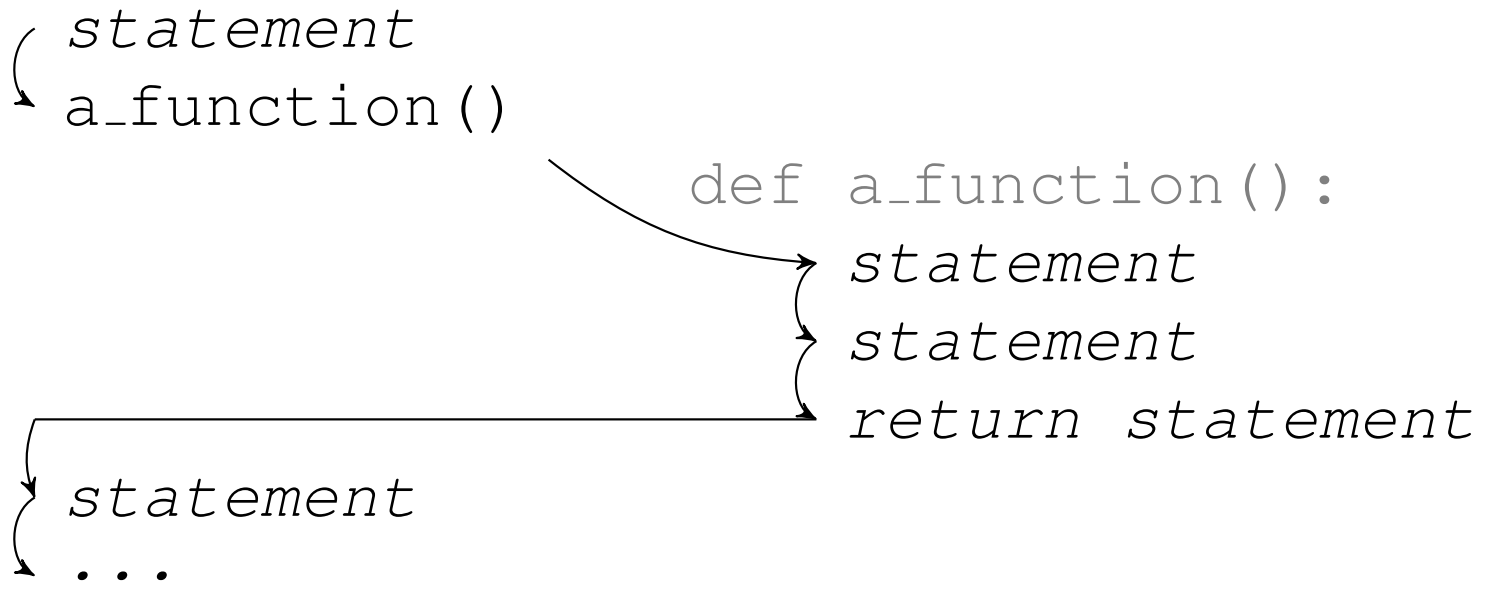
* Program control flow
* Branching: The `if` statement
* Recursion

Program control flow

Sequential program execution

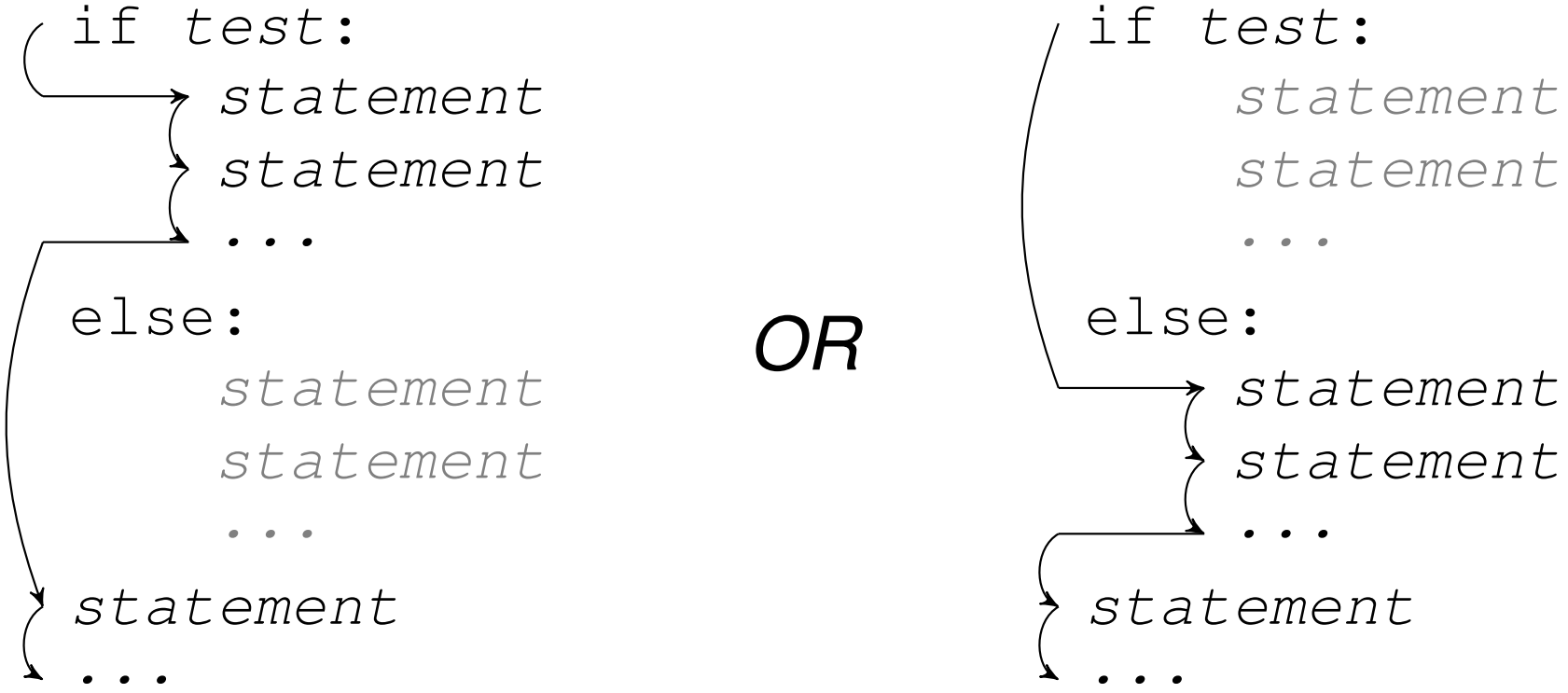


* The python interpreter always executes instructions (statements) one at a time in sequence.



* Function calls “insert” a function suite into this sequence, but the sequence of instructions remains invariably the same.

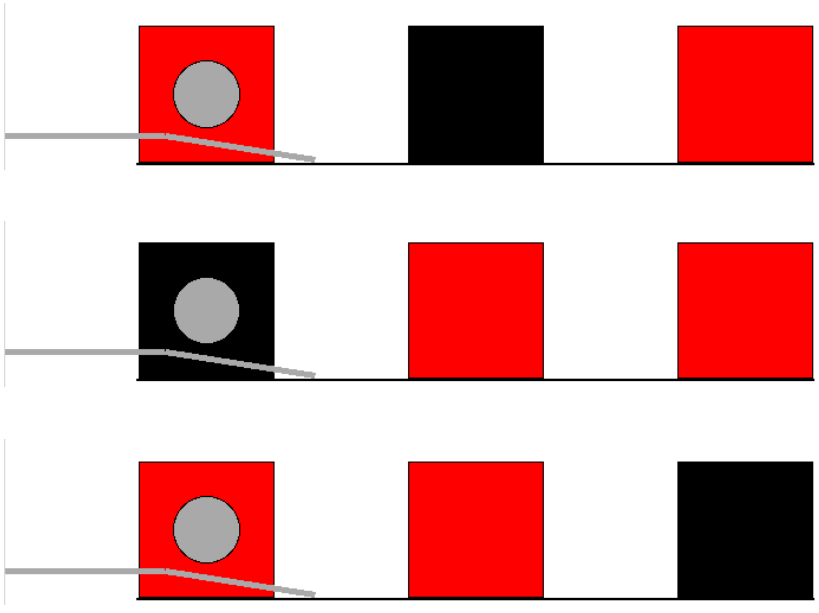
Branching program flow



* Depending on the outcome of a test, the program executes one of two alternative branches.

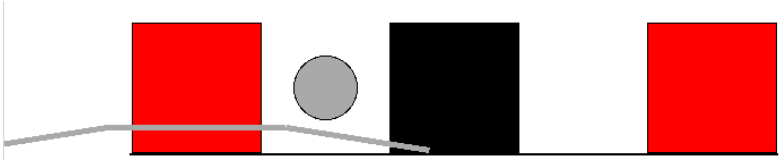
Problem: Stack the red boxes

* Two of three boxes on the shelf are red, and one is not; stack the two red boxes together.
* Write a program that works wherever the red boxes are.



* `robot.sense_color()` returns the color of the box in front of the sensor, or no color (`''`) if no box detected.

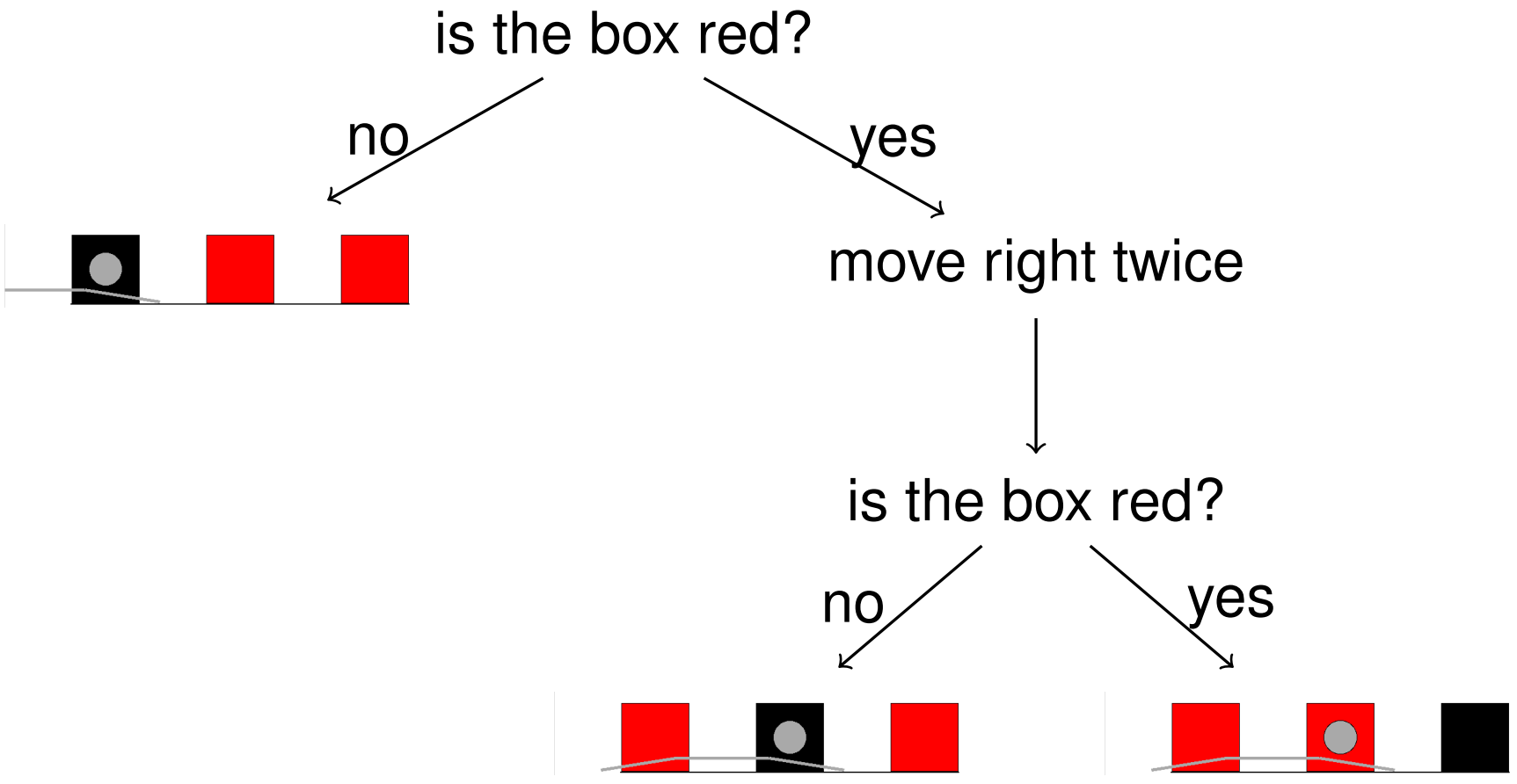
```
>>> robot.sense_color()
'red'
```



```
>>> robot.sense_color()
''
```

- Note that the color name is a string (in `''`)
- The box sensor is one step right of the gripper.

Algorithm idea



The `if` statement

```
if test_expression :
    suite
statement(s)
```

1. Evaluate the test expression (converting the value to type `bool` if necessary).
2. If the value is `True`, execute the suite, then continue with the following statements (if any).
2. If the value is `False`, skip the suite and go straight to the following statements (if any).

The `if` statement, with `else`

```
if test_expression :
    suite_1
else:
    suite_2
statement(s)
```

1. Evaluate the test expression.
2. If the value is `True`, execute suite #1, then following statements (if any).
2. If the value is `False`, execute suite #2, then following statements (if any).

Truth values (reminder)

* Type `bool` has two values: `False` and `True`.
* Boolean values are returned by comparison operators (`==`, `!=`, `<`, `>`, `<=`, `>=`) and a few more.
* Ordering comparisons can be applied to pairs of values of the same type, for (almost) any type.
* *Warning #1*: Where a truth value is required, python automatically converts any value to type `bool`, but it may not be what you expected.
* *Warning #2*: Don't use arithmetic operators (`+`, `-`, `*`, etc.) on truth values.

Suites (reminder)

* A *suite* is a (sub-)sequence of statements.
* A suite must contain at least one statement!
* In python, a suite is delimited by indentation.
  - All statements in the suite **must be preceded by the same number of spaces/tabs** (standard is 4 spaces).
  - The indentation depth of the suite inside an `if` (and `else`) statement must be greater than that of the `if` (`else`).
* A suite can include nested suites (`if`'s, etc).

Suites: A side remark

* (Almost) Every programming language has a way of grouping statements into suites/blocks.
  - For example, in C, Java and many other:

```
if (expression) {
  suite
}
```

  - or in Ada or Fortran (post -77):

```
if expression then
  suite
end if
```

* The use of indentation to *define* suites is a python peculiarity.

```
def stack_red_boxes():
    if robot.sense_color() == 'red':
        drive_right_twice()
        if robot.sense_color() == 'red':
            # stack middle box on left
        else:
            # stack left box on right
    else:
        # stack middle box on right
```

```
def print_grade(mark):
    if mark >= 80:
        print("HD")
    if mark >= 70:
        print("D")
    if mark >= 60:
        print("Cr")
    if mark >= 50:
        print("P")
    if mark < 50:
        print("Fail")
```

* What will `print_grade(90)` print?

Boolean operators

* The operators `and`, `or`, and `not` combine truth values:

a `and` *b*	`True` iff *a* and *b* both evaluate to `True`.
a `or` *b*	`True` iff at least one of *a* and *b* evaluates to `True`.
`not` *a*	`True` iff *a* evaluates to `False`.

* Boolean operators have lower precedence than comparison operators (which have lower precedence than arithmetic operators).

```
def print_grade(mark):
    if mark >= 80:
        print("HD")
    if mark < 80 and mark >= 70:
        print("D")
    if mark < 70 and mark >= 60:
        print("Cr")
    if mark < 60 and mark >= 50:
        print("P")
    if mark < 50:
        print("Fail")
```

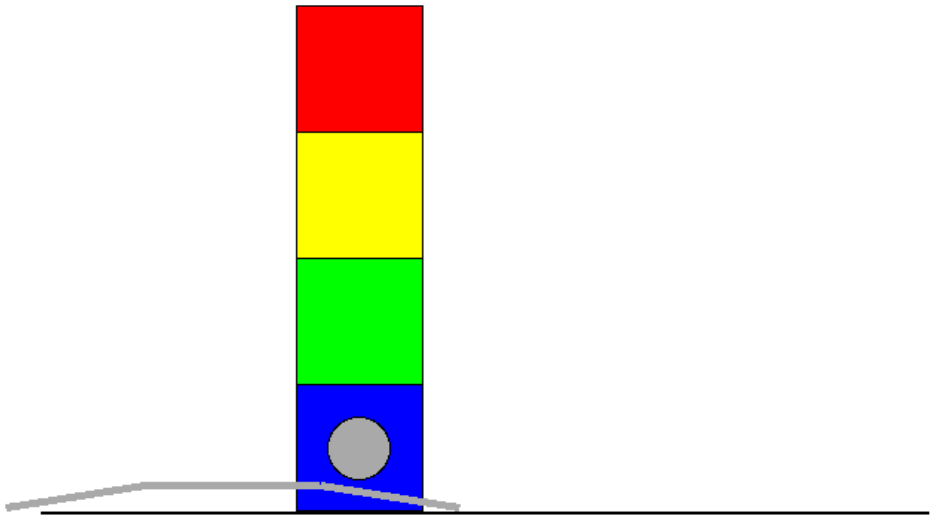
Recursion

Recursion

* The suite of a function can contain function calls, including *calls to the same function*.
  - This is known as *recursion*.
* The function suite must have a branching statement, such that a recursive call does not always take place ("base case"); otherwise, recursion never ends.
* Recursion is a way to think about solving a problem: how to reduce it to a simpler instance of itself?

Problem: Counting boxes

* How many boxes are in the stack from the box in front of the sensor and up?

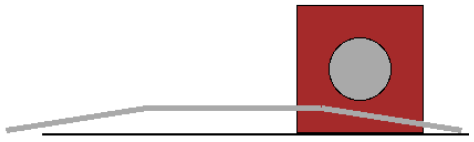


* If `robot.sense_color() == ''`, then the answer is zero.
* Else, one plus what the answer would be if the lift was one level up.

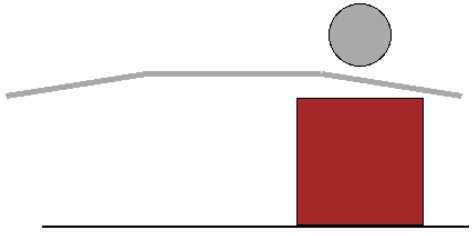
```
def count_boxes():
    if robot.sense_color() == '':
        return 0
    else:
        robot.lift_up()
        num_above = count_boxes()
        robot.lift_down()
        return 1 + num_above
```

The call stack (reminder)

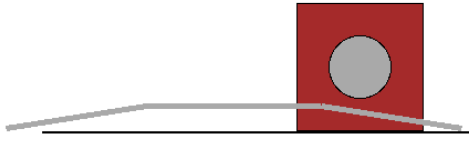
* When a function call begins, the current instruction sequence is put “on hold” while the function suite is executed.
* Execution of a function suite ends when it encounters a `return` statement, or reaches the end of the suite.
* The interpreter then returns to the next instruction after where the function was called.
* The *call stack* keeps track of where to come back to after each current function call.



```
1  ans = count_boxes()
2      if robot.sense_color() == '':
3          robot.lift_up()
```



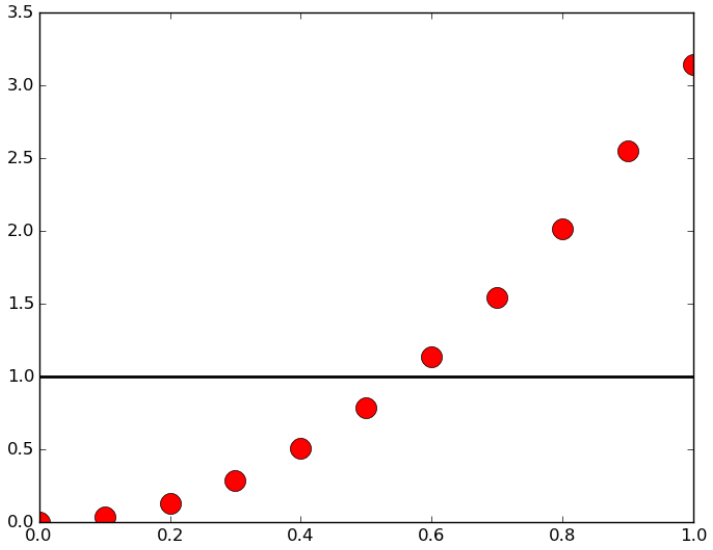
```
4          num_above = count_boxes()
5              if robot.sense_color() == '':
6                  return 0
7          num_above = 0
8          robot.lift_down()
```



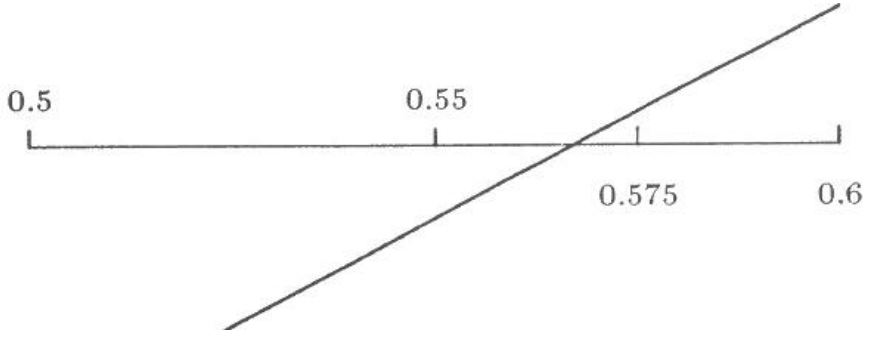
```
9          return num_above + 1
10 ans = 1
```

Problem: Solving an equation

* Solve $f(x) = 0$.
* For example, find r such that $r^2\pi = 1$.



* The interval-halving algorithm.



* Assumption: $f(x)$ is monotone increasing and crosses 0 in the interval $[l, u]$.
* Idea:
  - Find the middle of the interval, m:
  - if $f(m) \approx 0$, we're done;
  - if $f(m) < 0$, the solution lies in $[m, u]$;
  - if $f(m) > 0$, the solution lies in $[l, m]$.

* *Don't compare* `float`***s with*** `==`.