COMP1730/COMP6730
Programming for Scientists

Control, part 2: Iteration

Announcements

* Mid-semester exam has been (tentatively) scheduled for the 3rd of April (Wednesday in week 6).
  - The exam will take place in labs (CSIT, ENGN, and CS/MSI buildings).
  - Two sessions: 6:00pm and 8:00pm.
  - If you have any question/issue with the *exam schedule*, contact *student admin* and/or *the timetabling office*.
  - More information about the exam content will be on the course web site next week.

Outline

* Iteration: The `while` statement
* Simulations.

Program control flow

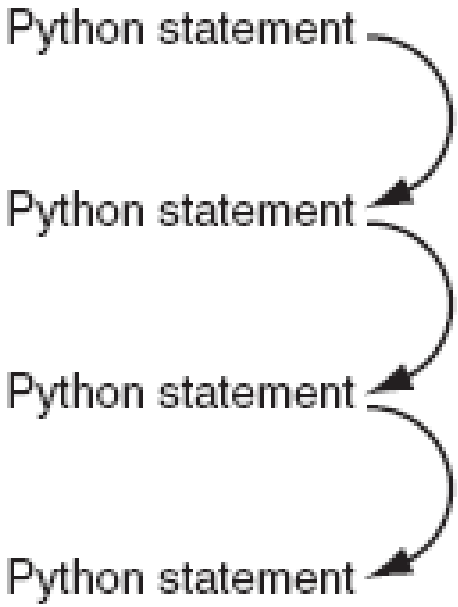


FIGURE 2.1 Sequential program flow.

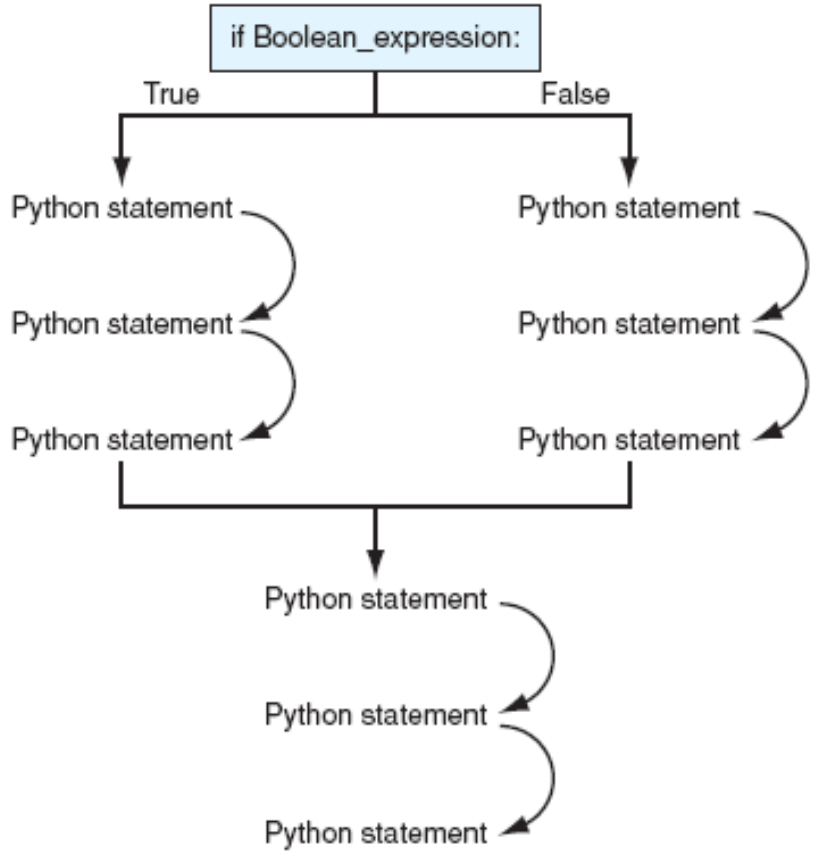
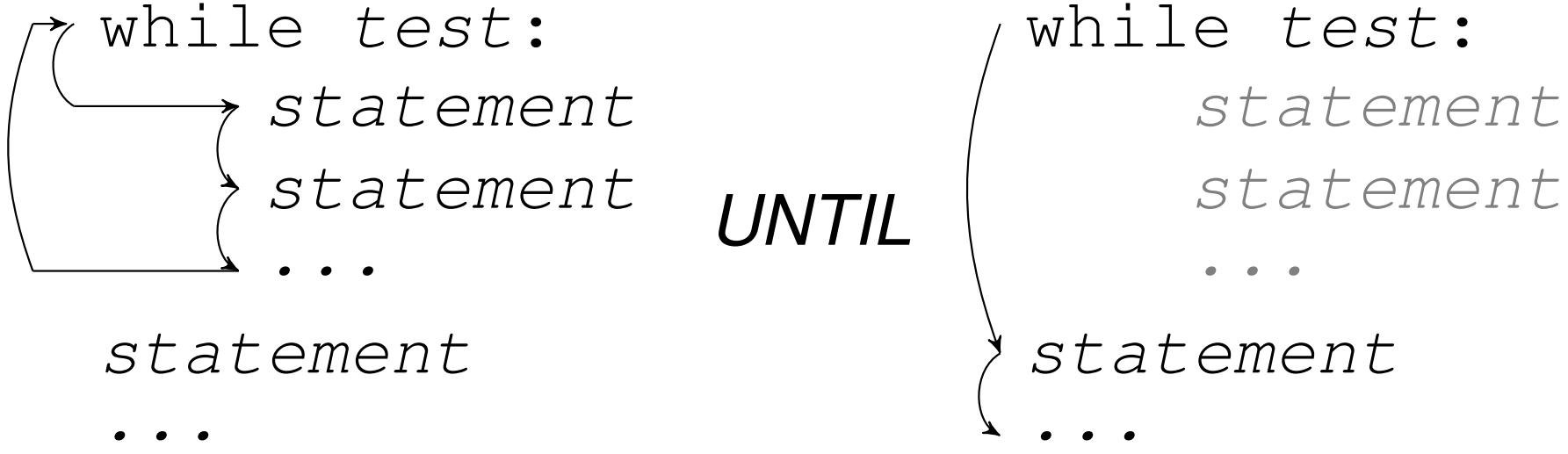


FIGURE 2.2 Decision making flow of control.

Images from Punch & Enbody

Iteration (Repetition)



* Iteration *repeats* a suite of statements.
* A test is evaluated before each iteration, and the suite executed (again) if it is true.

Iteration statements in python

* The `while` loop repeats a suite of statements as long as a condition is true.
* The `for` loop iterates through the elements of a collection or sequence (data structure) and executes a suite once for each element.
  - We'll come back to the `for` loop later in the course.

The `while` loop statement

```
while 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 once, then go back to **1**.
3. If the value is `False`, skip the suite and go on to the following statements (if any).

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 following `if` / `else` / `while` `:` must be greater than that of the statement.
* A suite can include nested suites (`if`'s, etc).

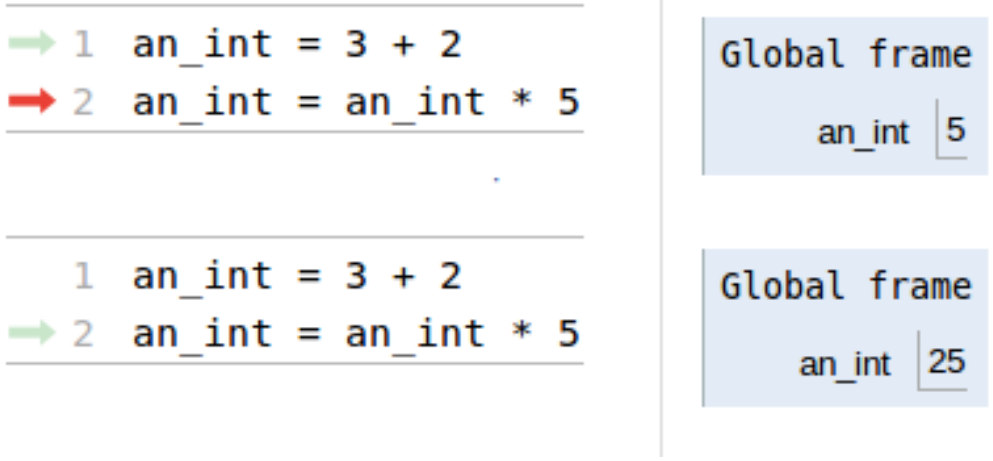
Variable assignment (reminder)

* A variable is a name that is associated with a value in the program.
* Variable assignment is a statement:

```
var_name = expression
```

  - Note: Equality is written == (two ='s).

* A name–value association is created by the *first* assignment to the name;
* *subsequent* assignments to the same name *change* the associated value.



* For example,

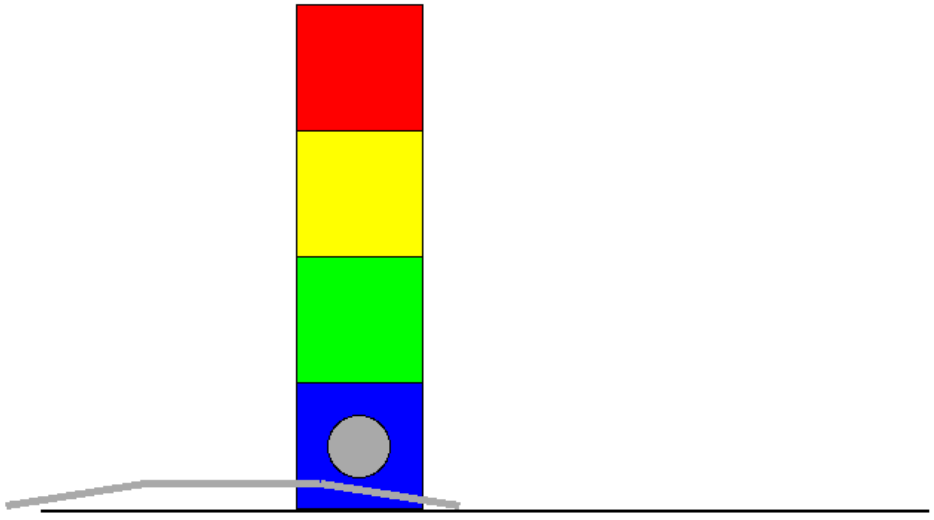
```
an_int = 3 + 2
an_int = an_int * 5
```

(From `pythontutor.com`)

1. Evaluate expression `3 + 2` to `5`.
2. Store value `5` with name `an_int`
3. Evaluate expression `an_int * 5` to `25`.
4. Store value `25` with name `an_int`, replacing the previous associated value.

Problem: Counting boxes

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

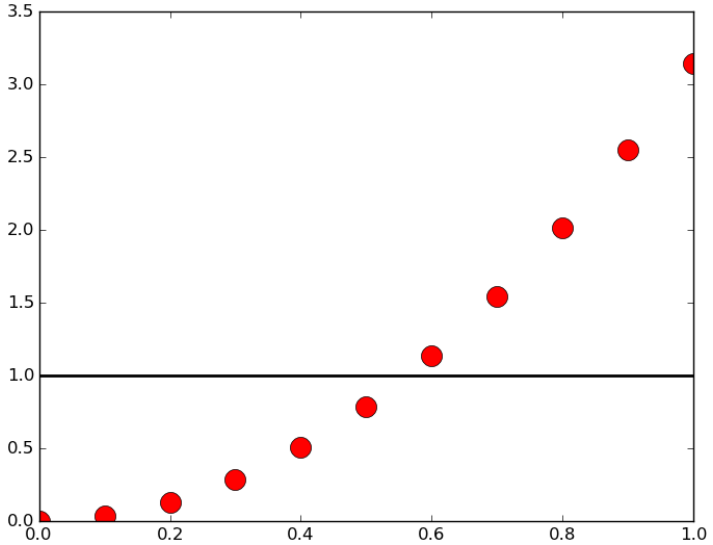


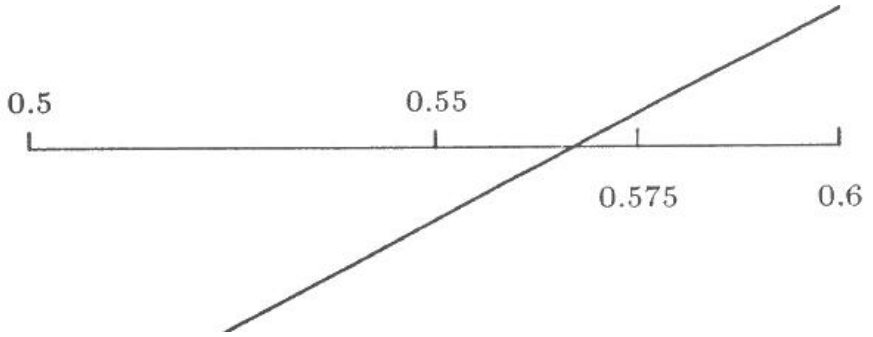
* While `robot.sense_color() != ''`, move the lift up, *and count how many times*; then move the lift down that many times.

```
def count_boxes():
    num_boxes = 0
    while robot.sense_color() != '':
        num_boxes = num_boxes + 1
        robot.lift_up()
    steps_to_go = num_boxes
    while steps_to_go > 0:
        robot.lift_down()
        steps_to_go = steps_to_go - 1
    return num_boxes
```

Problem: Solving an equation

* Solve $f(x) = 0$.
* The interval-halving algorithm:
  - if $f(m) \approx 0$, return m;
  - if $f(m) < 0$, set l to m;
  - if $f(m) > 0$, set u to m.





`return` from a loop

* A loop (`while` or `for`) can appear in a function suite, and a `return` statement can appear in the suite of the loop.

```
def find_box(color):
    while robot.sense_color() != '':
        if robot.sense_color() == color:
            return True
        robot.lift_up()
    return False
```

* Executing the `return` statement ends the function call, and therefore also exits the loop.

Common problems with `while` loops

* Loop never starts: the control variable is not initialised correctly.
* Loop never stops (infinite loop): the control variable is not modified in the loop.
* Loop runs one to many or one to few times (off by one error).

Simulation

Problem: How high does the Falcon 9 fly?

* Acceleration is thrust (force) divided by mass.
* 90%–96% of mass is fuel.
* Rocket's engines have about 7.5% more thrust in vacuum than at sea level.

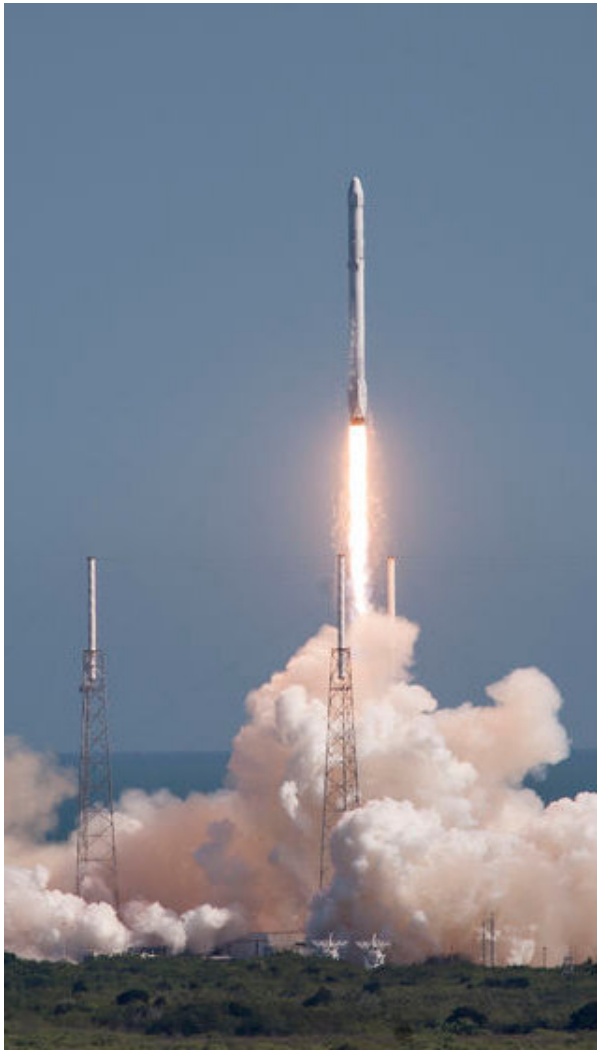


Image by SPACEX

Simulation

* Approximate the evolution of a complex group of coupled processes.
* Simulate time by small steps (δt):
  - At each step, compute the change in each variable over δt using the current values of other variables.

Example: Rocket simulation

* Altitude (a): $\delta a = v \cdot \delta t$
* Velocity (v): $\delta v =$ acceleration $\cdot \delta t$
* acceleration $=$ (thrust(a)$/m$) $- g$
  - assuming thrust(a) grows linearly between sea level pressure and vaccuum (probably wrong).
* Mass (m):
  - at time 0, $m =$ take-off weight.
  - $\delta m = -B \cdot \delta t$.
  - burn rate $B =$ take-off fuel weight $/$ burn time.

Example: Simulating the spread of a pandemic

* At each timestep:
  - Some proportion of infected cases recover
  - Some proportion of infected cases die
  - The infection can spread to healthy people
  - People can move (both infected and healthy)
* The simulation can be carried out at different resolutions of time and space.
* Allows planners to test different responses (road closures, treatment centres, etc.) to determine which might be the most effective.