COMP1730/COMP6730
Programming for Scientists

Control, part 2: Iteration

Outline

- Iteration: The `while` statement
- Simulations.
- Common problems with loops.

Iteration

Program control flow

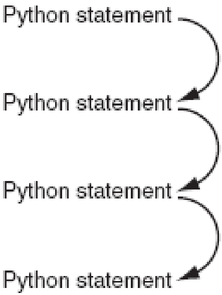


FIGURE 2.1 Sequential program flow.

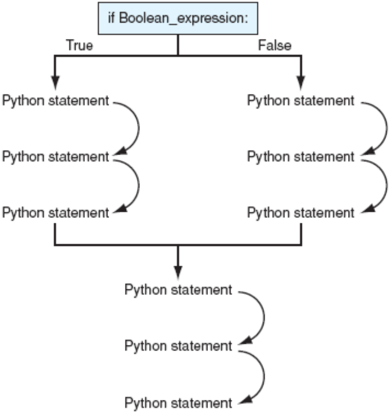
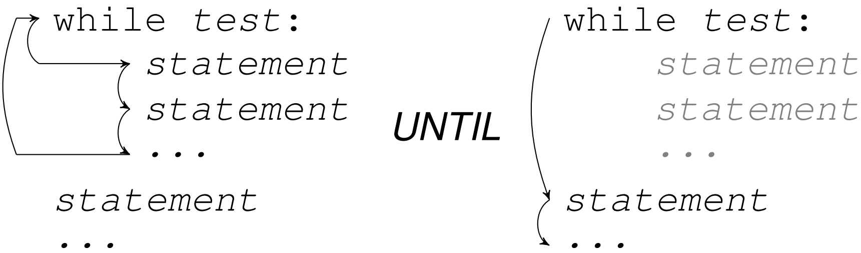


FIGURE 2.2 Decision making flow of control.

Images from Punch & Enbody

Iteration



```
while test:
    statement
    statement
    ...
statement
...
```

UNTIL

```
while test:
    statement
    statement
    ...
statement
...
```

- 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)

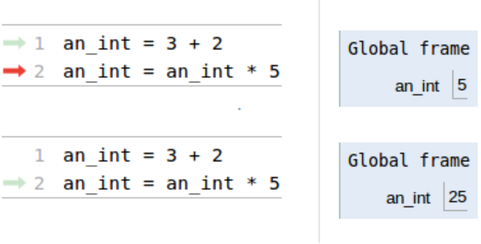
- A variable is a name that is associated with a value in the program.
- Variable assignment is a statement:

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



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

Global frame

an_int 5

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

Global frame

an_int 25

(From `pythontutor.com`)

1. Evaluate expression `2 + 3` to `5`.
2. Set value of `an_int` to `5`.
3. Evaluate expression `an_int * 5` to `25`.
4. Set value of `an_int` to `25`.

Example: Sums

- What is the max *k* such that $\left(\sum_{i=1,\ldots,k} i\right) \leq 20$?

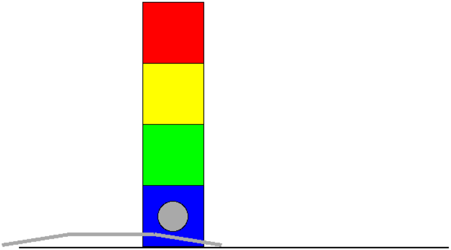
```
k = 1
sum_to_k = 1
while sum_to_k <= 20:
    print("k =", k, ", sum =", sum_to_k)
    k = k + 1
    sum_to_k = sum_to_k + k

print("The answer is", k - 1)
```

- Is this correct? (Test, test, test!)

Problem: Counting boxes

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

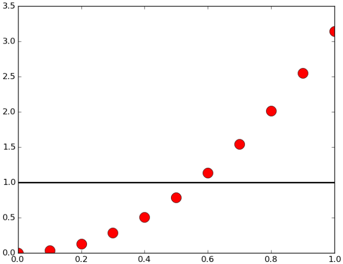


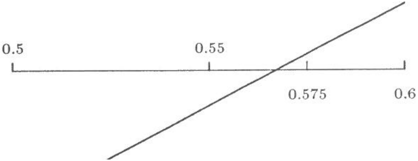
- While `robot.sense_color() == ''`, move the lift up, *and count how many times*; then move the lift down that many times.

```
def count_boxes():
    num_boxes = 0
    num_up = 0
    while robot.sense_color() != ’’:
        num_boxes = num_boxes + 1
        num_up = num_up + 1
        robot.lift_up()
    while num_up > 0:
        robot.lift_down()
        num_up = num_up - 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(colour):
    while robot.sense_color() != ’’:
        if robot.sense_color() == colour:
            return True
        robot.lift_up()
    return False
```

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

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.

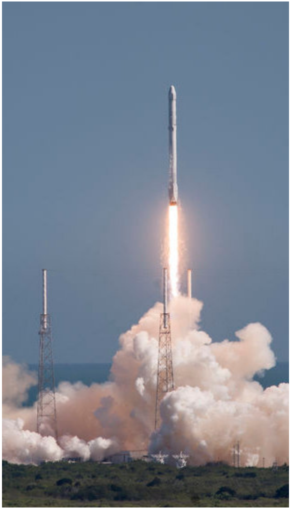


Image by SPACEX

Simulation

- Approximate the evolution of a complex 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): $\delta v = \text{acceleration} \cdot \delta t = (F/m) \cdot \delta t$
- Force: $F = \text{thrust}(a) - \text{gravity}$
  - 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: The Competitive Lotka-Volterra model of ecology

- The change in the population of species *i* is

  $$\delta x_i/\delta t = r_i x_i \left(1 - \left(\frac{x_i+\sum_{j\neq i} a_{ij}x_j}{K_i}\right)\right)$$

  where

  - r_i is the inherent growth rate of species *i*;
  - a_{ij} is the (negative) effect of species *j* on species *i*;
  - K_i is the population of species *i* that the environment can support (“carrying capacity”).

Writing and debugging loops

Repeat while condition is true

- A `while` loop repeats as long as the condition (test expression) evaluates to `True`.
- If the condition is initially `False`, the loop executes zero times.
- If no variable involved in the condition is changed during execution of the suite, the value of the condition will not change, and the loop will continue forever.

Common problems with `while` loops

- Loop never starts: the control variable is not initialised correctly.

```
# find smallest divisor of num:
i = 1
while num % i != 0:
    i = i + 1
```

  - `num % 1` is always `0`!

Common problems with `while` loops

- Loop never ends: the control variable is not updated in the loop suite, or not updated in a way that can make the condition false.

```
i = 0
while i != stop_num:
    i = i + step_size
```

  - What if `stop_num < 0`?
  - or `step_size < 0`?
  - or `step_size` does not divide `stop_num`?