Australian National University

COMP1730/COMP6730
Programming for Scientists

Control, part 2: Iteration

Outline

* Iteration: The `while` statement with examples
* Common problems with loops.

Program control flow

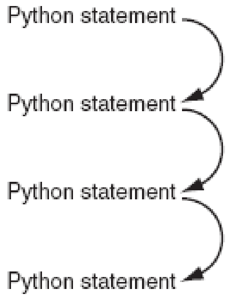


FIGURE 2.1 Sequential program flow.

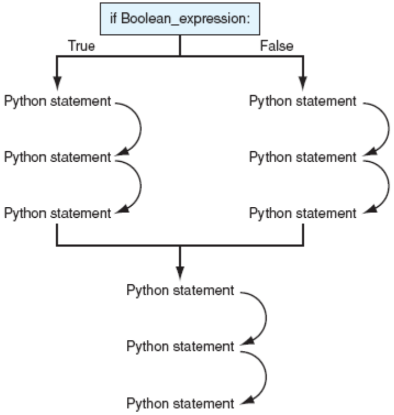
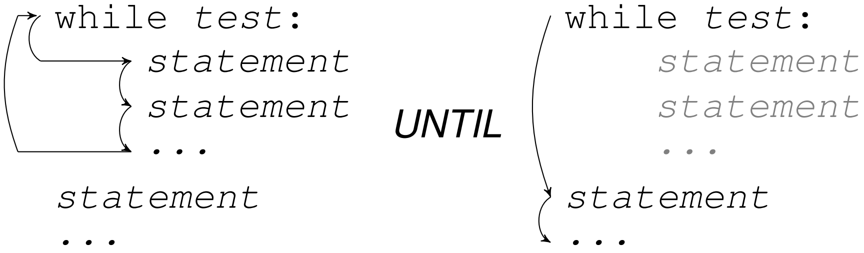


FIGURE 2.2 Decision making flow of control.

Images from Punch & Enbody

Iteration



```
while test:                         while test:
    statement                           statement
    statement          UNTIL            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 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).

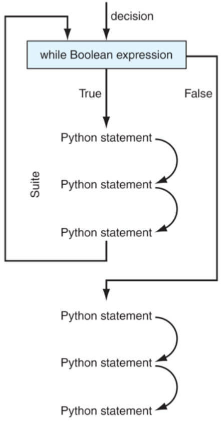


Image from Punch & Enbody

Suites (reminder)

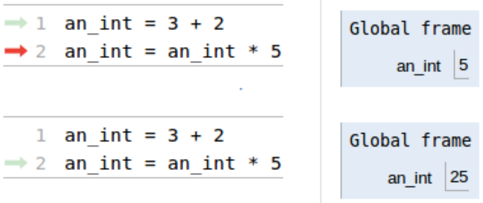
- A *suite* is a (sub-)sequence of statements.
- A suite must contain at least one statement!
- In python, a suite is delimited by indentation.
  - All statements in the suite **must be preceded by the same number of spaces/tabs** (standard is 4 spaces).
  - The indentation depth of the suite following `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.



```
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`)

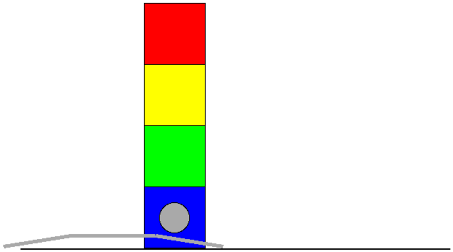
- For example,

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

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?

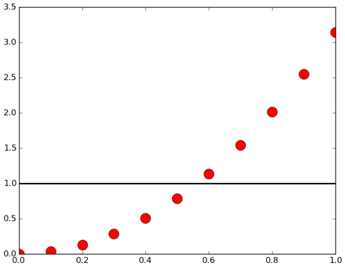


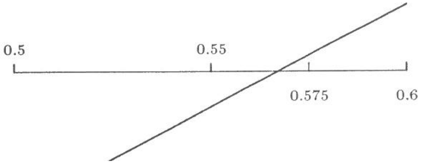
- While `robot.sense_color() != ''`, move the lift up, *and count how many times*; then move the lift down that many times.

```
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.

Problem: Greatest common divisor

- For two positive integers *a* and *b*, find the largest integer that divides *a* and *b*.
- Euclid's algorithm: Assuming $a \geq b$,
  - $gcd(a, b) = b$ if *b* divides *a*;
  - $gcd(a, b) = gcd(b, a\%b)$, otherwise.

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 non-trivial
# 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`?

Take home message

* Branching (`if`) and iteration (`while` loop) are two main control mechanisms to change the sequential flow of a program.
* Some (but not always) recursions can be re-written as iterations to solve the same problem (and vice versa).
* Make sure that the test condition will evaluate to `False` at some point. Otherwise you will enter an infinite loop!