Looping with `for`

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Introduction

Lecture topics

- the (lack of) limitations of `while` loops
- `for` statements and their semantics
- `for` as a *limited* form of `while`

while **loops**

while loops

Potential issues

- While loops specify unbounded iteration
- This means that the number of iterations is not necessarily easy to specify
- For example
  - Virtual machines
  - User-driven loops
  - Servers
  - Operating systems
  - ...

```
n,m = input("Let's have two numbers")
cnt = 1
while n > m:
    cnt = cnt + 1
    n = n / m
print("Result is %d" % cnt)
```

What does this code do?

How many steps does it take?

Unbounded loop example

```
quit = False
while not quit:
    action = raw_input("Should I quit?")
    if (action == "Yes") | (action == "yes"):
        quit = True
    else:
        print("You are not a quitter.")
```

What does this code do?

How many steps does it take?

```
y = 10.0
vy = 0.0
dt = 0.05
while (abs(vy) > 0.9) | (y > 0.2):
  new_y = y + vy * dt
  if new_y <= 0.1:
    vy = -vy * 0.7
  else:
    vy -= 9.8 * dt
    y = new_y
  ... draw a ball at position (10,y) ...
```

What does this code do?

https:
//github.com/hogeschool/INFDEV01-1/blob/master/
code/bouncing%20ball%20sample/bouncing%20ball.py

How many steps does it take?

while loops

Potential issues

- `while` loops are very powerful
- with great power comes...

Potential issues

- `while` loops are very powerful
- with great power comes...
- ...greater chance of bugs

while loops

Potential issues

- Subtle changes might affect behaviour deeply
- For example, a change in value of `0.1` makes the loop non-terminating
- The culprit may be hidden in a lot of places
  - Floating point errors
  - Logical repetition: state always changes, within a circular trajectory
  - ...

Unbounded loop example

```
y = 10.0
vy = 0.0
dt = 0.05
while (abs(vy) > 0.9) | (y > 0.1):
  new_y = y + vy * dt
  if new_y <= 0.1:
    vy = -vy * 0.7
  else:
    vy -= 9.8 * dt
    y = new_y
... draw a ball at position (10,y) ...
```

Does this loop terminate? (This is not the same code as in Slide 8!)

```
y = 10.0
vy = 0.0
dt = 0.05
while (abs(vy) > 0.9) | (y > 0.1):
  new_y = y + vy * dt
  if new_y <= 0.1:
    vy = -vy * 0.7
  else:
    vy -= 9.8 * dt
    y = new_y
... draw a ball at position (10,y) ...
```

Does this loop terminate? (This is not the same code as in Slide 8!)

No. The condition has changed to y > 0.1.

```
y = 10.0
vy = 0.0
dt = 0.1
while (abs(vy) > 0.9) | (y > 0.2):
  new_y = y + vy * dt
  if new_y <= 0.1:
    vy = -vy * 0.8
  else:
    vy -= 9.8 * dt
    y = new_y
  ... draw a ball at position (10,y) ...
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Does this loop terminate? (This is not the same code as in Slide 8!)

Unbounded loop example

```
y = 10.0
vy = 0.0
dt = 0.1
while (abs(vy) > 0.9) | (y > 0.2):
  new_y = y + vy * dt
  if new_y <= 0.1:
    vy = -vy * 0.8
  else:
    vy -= 9.8 * dt
    y = new_y
  ... draw a ball at position (10,y) ...
```

Does this loop terminate? (This is not the same code as in Slide 8!)

No. `dt = 0.1` and `vy = -vy * 0.8`.

Correctly encoding intentions

Why is `while` not enough

- The expressive power of `while` is not always needed
- Sometimes we want something simpler, and less dangerous
- For example, consider:
  - For each *hostile alien*
  - Do *attack it*

Why is `while` not enough

- A loop such as:
  - For each *hostile alien*
  - Do *attack it*

- Is predictable

- Performs a fixed number of steps (one per hostile alien)

- Will certainly terminate

Why is `while` not enough

- In general, we wish to always correctly encode our intention of repeating code N times
- The code must precisely fit our intentions, like a tailored italian suit
  - Code should not be too complicated
  - Code should not be too simple

Code that is too complicated?

- A `while` loop where we need to perform `N` steps
- There are many subtle ways to break the code

Code that is too complicated?

- Classes, objects, and inheritance everywhere
- To know which code is actually run to say `Hello world!` you need to read twelve files

Code that is too complicated?

- Events, lambda's, higher-order combinators everywhere
- To know what the program does you need two doctorates (CompSci and Maths)
  - Plus internal access to the sliced brain of the original programmer

Code that is too simple?

- No handling of error cases
- Ignoring hard circumstances

Code that is too simple?

- No handling of error cases
- Ignoring hard circumstances
- Not implementing all features correctly
  - Showing progress off
  - Building impressive but pointless demo's

Iterating with `for`

Code that is too simple?

- Python, and many other modern languages, offer explicit constructs for bounded repetition
  - We specify precisely the number of steps that need to be performed
  - The language takes care of performing the right number of steps
  - The construct is much harder to break[a] than a `while`-loop
- These constructs are called for-loops

---

[a]Running forever

Syntax of `for`

- Number of repetitions (a `range` iterator)
- That stores the index of the current repetition (a variable)
- Body of the loop that is repeated at every iteration (a block of code)

```
for VARIABLE in range(END):
  BODY
```

- VARIABLE is any valid variable name that becomes useable within the BODY; will range from 0 to END-1
- END is any positive number; the body will be repeated END-1 times
- BODY is a series of statements

Iterating with `for`

Semantics of `for`

- The general form is `for VAR in RANGE: BODY` (f_{VRB})
- If `VAR` is still within `RANGE`, then we jump to the beginning of `BODY` and then increment the variable, otherwise we jump to the end of the whole `for`

$$\begin{cases} (PC, S) \stackrel{f_{VRB}}{\to} (firstLine(B), S) & when & S[V] \in R \\ (PC, S) \stackrel{f_{VRB}}{\to} (skipAfter(B), S) & when & S[V] \notin R \end{cases}$$

- At the end of the loop assume that we have two invisible instructions
  - `V = V + 1`
  - `jump back to begin loop`

Index of the current repetition

- The `BODY` of the `for` loop is always the same
- Depending on the current step, we may perform different processing
- For this, we need to know how far we have come in the loop
  - The iteration `VARIABLE` tells us this

```
graph = ""
for i in range (11):
    for j in range ((i-5) * (i-5)):
        graph += '='
    graph += "\n"
print (graph)
```

What does this do?

How do the different steps perform different actions based on the value of the iteration variable(s)?

Index of the current repetition

- Different processing per different steps makes the loop perform a more complex operation.
- Complex is not the same as complicated.
- To avoid needless complication, the different steps must still do related things

```
for i in range(6):
  if i == 0:
    #...run a game of tic-tac-toe...
  elif i == 1:
    #...draw a smiley...
  elif i == 2:
    #...run a turtle program...
  elif i == 3:
    #...convert degrees to fahrenheit...
  elif i == 4:
    #...draw a square...
  elif i == 5:
    #...draw a triangle...
```

What is the relationship between the iterations?

Is a `for` loop really needed?

Body of the loop

- The code of the body is a block of code
- A block of code is any statement or series of statements
- Among these statements, we can use as many `if`'s, `for`'s, and `while`'s

Body of the loop

- There is no *obfuscated code* prize available
- Nesting too many complex constructs might make code **needlessly complicated**
- Remember that a `for`-loop adds a large number of possible execution paths, just like a `while`-loop

Advanced loops

Ranges of iteration

- We do not always want to iterate through values between 0 and a given number
- Even though we still need to perform a fixed number of steps
- So a `for`-loop still has advantages over a `while`-loop

We might want to...

- ...decrement instead of increment, that is "go backwards"
- ...iterate between a range of values that does not start with zero
- ...take steps of more than one between iterations

The `range` function

- Actually takes three parameters: `range(start, end, step)`
- With one parameter we only specify `end`, while `start = 0` and `step = 1`
- With two parameters we specify `start` and `end`, while `step = 1`
- With all parameters we specify `start`, `end`, and `step`

```
for i in range(2, 10, 1):
  print(i)
```

```
for i in range(0, 20, 5):
  print(i)
```

```
for i in range(10, 0, -1):
    print("                \r" + str(i)),
    sleep(0.3)
print("\rBOOOM!!!!!")
```

Nesting `for`-loops

- The `BODY` of a `for`-loop contains arbitrary code
- This arbitrary code may also contain loops
- Loops within loops have a "multiplicative" behaviour
  - A loop of `M` step within a loop of `N` steps performs `N*M` steps

```
cnt = 0
for i in range(10):
  for j in range(5):
    cnt += 1
print(cnt)
```

Advanced loops

Nesting `for`-loops

- Each loop adds its own iteration variable
- The iteration variables, together, are an N-dimensional point
- A single loop performs a "linear" computation, two loops perform a "square" computation, three perform a "cubic" computation, etc.

Advanced loops

Nesting `for`-loops

- Multiple `for`-loops perform a predetermined number of computations
- This means that we can always translate multiple `for`-loops into a single one[a]

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[a]This will usually break readability, so it is not advised: it is just a reasoning exercise.

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for

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Introduction

while loops

Correctly
encoding
intentions

Iterating with
for

Advanced
loops

Conclusion

```
for i in range (0 ,10):
  for j in range (0 ,5):
    print (i,j)
```

can be simulated with

```
for x in range (0 ,50):
  i = x / 5
  j = x % 5
  print (i, j)
```

Conclusion

Conclusion

- `while`-loops can encode any form of iteration.
- When the number of iterations is known beforehand, while is too powerful
- To use the right level of abstraction (which is less sensitive to bugs), we use `for`-loops instead
- This allows us to instruct the language to perform exactly the required number of steps, usually with less code

The best of luck, and thanks for the attention!