Functions

TEAM INFDEV

Hogeschool Rotterdam
Rotterdam, Netherlands

Introduction

Introduction

Lecture topics

- Mechanism of abstraction
- The need for functions
- Functions in Python

What is abstraction?

What is abstraction?

Introduction

- The big issue of the whole course is **abstraction** in programming
- Abstraction is a fundamental concept in programming to reduce repetition
- We sit atop a mountain of abstraction, which we make taller at every iteration

What is abstraction?

Grab the student next to you

- Describe what you just did so that someone else can perform the same action

What is abstraction?

Grab the student next to you

- Describe what you just did so that someone else can perform the same action
- Now add specific details about the movements of your arm and phalanges (pieces of fingers)

What is abstraction?

Grab the student next to you

- Describe what you just did so that someone else can perform the same action
- Now add specific details about the movements of your arm and phalanges (pieces of fingers)
- Now realize that there are even more subcomponents: individual muscles, tendons, etc.

What is abstraction?

Grab the student next to you

- Describe what you just did so that someone else can perform the same action
- Now add specific details about the movements of your arm and phalanges (pieces of fingers)
- Now realize that there are even more subcomponents: individual muscles, tendons, etc.
- But then we have also cells that make these up
- ...

What is abstraction?

Human love for abstraction

- Our brain cannot handle so many details
- To cope with this, we are structured in layers
- Our consciousness manipulates only the upper layers with simple instructions
- *Raise arm above head*

What is abstraction?

Human love for abstraction

- The same happens with regular language
- "*Go buy a liter of milk*" is quite a short description
- The underlying operation is very complex

Complexity of simple instructions


```
1  Go buy a liter of milk =
2    Turn game off
3    Get up from the couch
4    Curse the instruction giver
5    Get dressed
6    Put money in pocket
7    Leave house
8    Reach nearest shop
9    Enter shop
10   Find milk
11   Take one liter bottle
12   Pay milk
13   Go home
14   Give milk to instruction giver
```

What is abstraction?

Human love for abstraction

- And clearly something like "*reach nearest shop*" is not a trivial instruction by itself
- Think about all the things you give for granted
  - Crossing roads
  - Traffic lights
  - Pathfinding
  - Road work and obstructions
  - Use of transportation methods
  - ...

Problem discussion

Problem discussion

Introduction

- Consider many operations on number
  - finding whether a number is prime
  - finding whether a number is odd or even
  - finding the Fibonacci value of a given number
  - ...

counting down..


```
1 cnt = startAt
2 while not(cnt == 0):
3   cnt = cnt - 1
4 print("Lift off!!!")
```

Introduction

counting down..


```
1 cnt = startAt
2 while not(cnt == 0):
3   cnt = cnt - 1
4 print("Lift off!!!")
```

Introduction

- What does `cnt` contain if `startAt` equals 10?
- What do we do with the value of startAt?
- Does it even matter?

Problem discussion

Introduction

- Suppose that we want another start, `newStartAt`
- How do we do it?

Lenght of a list


```
1
2 cnt = newStartAt
3 while not(cnt == 0):
4   cnt = cnt - 1
5 print("Lift off!!!")
```

Introduction

Lenght of a list


```
1
2 cnt = newStartAt
3 while not(cnt == 0):
4   cnt = cnt - 1
5 print("Lift␣off!!!")
```

Introduction

- Looks suspiciously like the previous code block
- Why?

General idea

General idea

Adding our own layers

- The goal of this lecture is to add a new layer of abstraction to our programs
- We wish to reuse **implementations**
- This layer of abstraction is called **functions**

Adding our own layers


```
+-------------+
| ...         |
+-------------------+
| Functions         |
+-------------------------+
| data structures         |
+-----------------------------+
| if, for, while, variables   |
+---------------------------------+
| (Python) runtime                |
+---------------------------------+
...
```

General idea

Description

- A function is a collection of instructions and variables
- Some instructions and variables are fixed inside its **body**
- Other instructions and variables come from outside the function, and thus are not fixed; these are called **parameters** of the function
- We try to strike the right balance between flexibility and work done
- The function returns a final result that can be recovered by the code that uses the function

Blueprint of a function (NOT ACTUAL PYTHON CODE!)


```
1  count_down starting from a number:
2    cnt = number
3    while not(cnt == 0):
4     cnt = cnt - 1
5    return "Lift␣off!!!" as final result
```

Description

Blueprint of a function (NOT ACTUAL PYTHON CODE!)


```
1  count_down starting from a number:
2    cnt = number
3    while not(cnt == 0):
4     cnt = cnt - 1
5    return "Lift␣off!!!" as final result
```

Description

- `count_down` is the **function name**
- `number` is the only **parameter**
- Lines 2 through 4 are **fixed**
- `"Lift off!!!"` is the **final result**

General idea

Using the function

- Code that needs a count down function can now simply invoke function `count_down`
- The resulting code will simply be `result = count_down(5)`
- `result` will be assigned with the value returned by the function, i.e., "Lift off!!!"

Technical details

Technical details

Introduction

- A function can be defined in Python quite easily
- The syntax is:
  - `def <<name>>(<<parameters>>):`[a][b]
    - `body`
    - `return <<result>>`
- Inside a function we can put whatever instructions we need
  - `if`
  - `for`
  - ...

[a] Parameters might be none, thus we can write simply `()`

[b] Multiple parameters are separated by a comma, thus `(<<p1>>,<<p2>>,...,<<pn>>)`

Technical details

Using the function

- After we declare a function, we can use it
- The syntax is quite simple
  - `<<name>>(<<parameters>>)` to just call the function and ignore the result
  - `<<v>> = <<name>>(<<parameters>>)` to call the function and assign the result to the `<<v>>` variable
- After calling the function, we enter the local environment of the function
- Variables, the `PC`, etc. are separate from those of the calling site

Runtime example

PC
6

```
1  def count_down(number):
2    cnt = number
3    while not(cnt == 0):
4      cnt = cnt - 1
5    return "Lift off!!!"
6  print(count_down(2))
```

Runtime example

PC
6

```
1  def count_down(number):
2    cnt = number
3    while not(cnt == 0):
4      cnt = cnt - 1
5    return "Lift off!!!"
6  print(count_down(2))
```

PC	count_down	PC	number
6	nil	2	2

Runtime example

PC	count_down	PC	number
6	nil	2	2

```
1  def count_down(number):
2    cnt = number
3    while not(cnt == 0):
4      cnt = cnt - 1
5      return "Lift off!!!"
6  print(count_down(2))
```

Runtime example

PC	count_down	PC	number
6	nil	2	2

```
1 def count_down(number):
2   cnt = number
3   while not(cnt == 0):
4     cnt = cnt - 1
5     return "Lift off!!!"
6 print(count_down(2))
```

PC	count_down	PC	number	cnt
6	nil	3	2	2

Runtime example

PC	count_down	PC	number	cnt
6	nil	3	2	2

```
1  def count_down(number):
2    cnt = number
3    while not(cnt == 0):
4      cnt = cnt - 1
5    return "Lift␣off!!!"
6  print(count_down(2))
```

Runtime example

PC	count_down	PC	number	cnt
6	nil	3	2	2

```
1 def count_down(number):
2   cnt = number
3   while not(cnt == 0):
4     cnt = cnt - 1
5   return "Lift␣off!!!"
6 print(count_down(2))
```

PC	count_down	PC	number	cnt
6	nil	4	2	2

Runtime example

PC	count_down	PC	number	cnt
6	nil	4	2	2

```
1  def count_down(number):
2    cnt = number
3    while not(cnt == 0):
4      cnt = cnt - 1
5    return "Lift off!!!"
6  print(count_down(2))
```

Runtime example

PC	count_down	PC	number	cnt
6	nil	4	2	2

```
1 def count_down(number):
2   cnt = number
3   while not(cnt == 0):
4     cnt = cnt - 1
5   return "Lift␣off!!!"
6 print(count_down(2))
```

PC	count_down	PC	number	cnt
6	nil	3	2	1

Runtime example

After a few steps...

PC	count_down	PC	number	cnt
6	nil	5	2	0

```
1 def count_down(number):
2   cnt = number
3   while not(cnt == 0):
4     cnt = cnt - 1
5   return "Lift off!!!"
6 print(count_down(2))
```

Runtime example

After a few steps...

PC	count_down	PC	number	cnt
6	nil	5	2	0

```
1 def count_down(number):
2   cnt = number
3   while not(cnt == 0):
4     cnt = cnt - 1
5   return "Lift off!!!"
6 print(count_down(2))
```

Do we still need all the local variables of the function?

Runtime example

After a few steps...

PC	count_down	PC	number	cnt
6	nil	5	2	0

```
1 def count_down(number):
2   cnt = number
3   while not(cnt == 0):
4     cnt = cnt - 1
5   return "Lift off!!!"
6 print(count_down(2))
```

Do we still need all the local variables of the function?
Where do we put the result?

Runtime example

After a few steps...

PC	count_down	PC	number	cnt
6	nil	5	2	0

```
1 def count_down(number):
2   cnt = number
3   while not(cnt == 0):
4     cnt = cnt - 1
5   return "Lift off!!!"
6 print(count_down(2))
```

Do we still need all the local variables of the function?
Where do we put the result?

PC	count_down
6	"Lift off!!!"

Technical details

Syntax and semantics

- We will now describe how Python functions work precisely
- This is a **fundamental** bit of knowledge that determines if you really do learn how to program or not
- This **absolutely requires** a lot of focus to get
- Please panic a bit on the inside

Technical details

Subtleties that make functions "fun" to use

- About variables
  - Variables and parameters inside a function have precise **scope** (visibility)
  - Primitive values given as parameters can be **changed only locally** to the function
  - References given as parameters can be **permanently changed** from within the function
  - Global variables defined outside the function may be **read but not changed** from within the function[a]
- About behaviour
  - A function may **call itself**, in a process known as **recursion**
  - A function may **get as parameters and return other functions**, in a process known as **higher order functions**

[a] **Unless you use some tricks we strongly discourage**

Technical details

Local and global variables (basics of scope)

- The parameters of a function are added to the list of accessible variables
- They are only visible from inside the function
- Global variables are also visible from inside the function

Technical details

Local and global variables (basics of scope)

- Every call to a function generates a new value of the stack memory S
- This contains (private copy of) all local variables
- The original stack memory (the **global variables**) remains accessible, just read-only

Technical details

Local and global variables (basics of scope)

- Every call to a function also reserves some special locations in the stack
- The local `PC` of the function
- The local variables of the function
- The returned value when the function is done

Locals and globals


```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  print(f(30))
8  x = 2
9  print(f(10))
```

Local and global variables (basics of scope)

- `x` is a global variable, visible outside and inside the function
- `z` is a local variable, visible only inside the function

Locals and globals


```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  print(f(30))
8  x = 2
9  print(f(10))
```

Local and global variables (basics of scope)

- `x` is a global variable, visible outside and inside the function
- `z` is a local variable, visible only inside the function
- **What does this program print?**

Locals and globals


```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  print(f(30))
8  x = 2
9  print(f(10))
```

Local and global variables (basics of scope)

- `x` is a global variable, visible outside and inside the function
- `z` is a local variable, visible only inside the function
- **What does this program print?**
- 10, 30, 20

Locals and globals

PC
1

```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
```

Locals and globals

PC
1

```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
```

PC	x
6	1

Locals and globals

PC	x
6	1

```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
```

Locals and globals

PC	x
6	1

```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
```

PC	x	f	PC	z
6	1	nil	4	10

Locals and globals

PC	x	f	PC	z
6	1	nil	4	10

```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
```

Locals and globals

PC	x	f	PC	z
6	1	nil	4	10

```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
```

PC	x	f
7	1	10

Locals and globals

PC	x	f
7	1	10

```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
```

Locals and globals

PC	x	f
7	1	10

```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
```

PC	x
8	2

Locals and globals

PC	x	f	PC	z
8	2	nil	4	10

```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
```

Locals and globals

PC	x	f	PC	z
8	2	nil	4	10

```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
```

PC	x	f
8	2	20

Locals and globals


```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
9  print(z)
```

Local and global variables (basics of scope)

- `x` is a global variable, visible outside and inside the function
- `z` is a local variable, visible only inside the function

Locals and globals


```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
9  print(z)
```

Local and global variables (basics of scope)

- `x` is a global variable, visible outside and inside the function
- `z` is a local variable, visible only inside the function
- **What does this program do?**

Locals and globals


```
1  x = 1
2
3  def f(z):
4    return x * z
5
6  print(f(10))
7  x = 2
8  print(f(10))
9  print(z)
```

Local and global variables (basics of scope)

- `x` is a global variable, visible outside and inside the function
- `z` is a local variable, visible only inside the function
- **What does this program do?**
- Crash with `NameError: name 'z' is not defined`

Locals and globals


```
1  def f(z):
2    z = z + 1
3    return z * 2
4
5  print(f(10))
6  print(f(30))
```

Local and global variables (basics of scope)

- z is a local variable, visible only inside the function

Locals and globals


```
1  def f(z):
2    z = z + 1
3    return z * 2
4
5  print(f(10))
6  print(f(30))
```

Local and global variables (basics of scope)

- z is a local variable, visible only inside the function
- **What does this program print?**

Locals and globals


```
1  def f(z):
2    z = z + 1
3    return z * 2
4
5  print(f(10))
6  print(f(30))
```

Local and global variables (basics of scope)

- z is a local variable, visible only inside the function
- **What does this program print?**
- 22, 62

Technical details

Shadowing

- The parameters of a function have priority over globals
- They supersede global variables of the same name

Shadowing


```
1  x = 1
2
3  def f(x):
4    return x * 2
5
6  print(f(10))
7  print(f(20))
```

Shadowing

- `x` is a global variable, potentially visible inside the function
- `x` is also a local variable of the function, which has priority over the global `x`

Shadowing


```
1  x = 1
2
3  def f(x):
4    return x * 2
5
6  print(f(10))
7  print(f(20))
```

Shadowing

- `x` is a global variable, potentially visible inside the function
- `x` is also a local variable of the function, which has priority over the global `x`
- **What does this program print?**

Shadowing


```
1  x = 1
2
3  def f(x):
4    return x * 2
5
6  print(f(10))
7  print(f(20))
```

Shadowing

- `x` is a global variable, potentially visible inside the function
- `x` is also a local variable of the function, which has priority over the global `x`
- **What does this program print?**
- 20, 40

Shadowing

PC	x
6	1

```
1  x = 1
2
3  def f(x):
4    return x * 2
5
6  print(f(10))
7  print(f(20))
```

Shadowing

PC	x
6	1

```
1  x = 1
2
3  def f(x):
4    return x * 2
5
6  print(f(10))
7  print(f(20))
```

PC	x	f	PC	x
6	1	nil	4	10

Shadowing

PC	x	f	PC	x
6	1	nil	4	10

```
1  x = 1
2
3  def f(x):
4    return x * 2
5
6  print(f(10))
7  print(f(20))
```

Shadowing

PC	x	f	PC	x
6	1	nil	4	10

```
1  x = 1
2
3  def f(x):
4    return x * 2
5
6  print(f(10))
7  print(f(20))
```

PC	x	f
7	1	20

Shadowing

PC	x	f
7	1	20

```
1  x = 1
2
3  def f(x):
4    return x * 2
5
6  print(f(10))
7  print(f(20))
```

Shadowing

PC	x	f
7	1	20

```
1  x = 1
2
3  def f(x):
4    return x * 2
5
6  print(f(10))
7  print(f(20))
```

PC	x	f	PC	x
7	1	nil	4	20

Shadowing

PC	x	f	PC	x
7	1	nil	4	20

```
1  x = 1
2
3  def f(x):
4    return x * 2
5
6  print(f(10))
7  print(f(20))
```

Shadowing

PC	x	f	PC	x
7	1	nil	4	20

```
1  x = 1
2
3  def f(x):
4    return x * 2
5
6  print(f(10))
7  print(f(20))
```

PC	x	f
8	1	40

Technical details

Recursion

- (Recursive) functions are all functions that call themselves in their bodies
- This is based on the principle of induction and in general a very powerful technique
- This leads to a compacter and often more easily correct representation
  - Code is not easier to read, especially to the untrained eye

Technical details

Recursion

- Remember that calling a function creates a new instance of stack memory
- Recursive functions do this a lot
- Each recursive call has its own environment

Recursion


```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
```

Recursion

- How much is the distance between two numbers `n` and `m`?

Recursion


```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
```

Recursion

- How much is the distance between two numbers `n` and `m`?
- As many as the units between them

Recursion

PC
7

```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
6
7  print(distance(2, 4)))
```

Recursion

PC
7

```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
6
7  print(distance(2, 4)))
```

PC	distance	PC	n	m
7	nil	2	2	4

Recursion

PC	distance	PC	n	m
7	nil	2	2	4

```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
6
7  print(distance(2, 4)))
```

Recursion

PC	distance	PC	n	m
7	nil	2	2	4

```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
6
7  print(distance(2, 4)))
```

PC	distance	PC	n	m
7	nil	5	2	4

Recursion

PC	distance	PC	n	m
7	nil	5	2	4

```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
6
7  print(distance(2, 4)))
```

Recursion

PC	distance	PC	n	m
7	nil	5	2	4

```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
6
7  print(distance(2, 4)))
```

PC	distance	PC	n	m	distance	PC	n	m
7	nil	5	2	4	nil	2	3	4

Recursion

PC	distance	PC	n	m	distance	PC	n	m
7	nil	5	2	4	nil	2	3	4

```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
6
7  print(distance(2, 4)))
```

Recursion

PC	distance	PC	n	m	distance	PC	n	m
7	nil	5	2	4	nil	2	3	4

```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
6
7  print(distance(2, 4)))
```

PC	distance	PC	n	m	distance	PC	n	m
7	nil	5	2	4	nil	5	3	4

Recursion

PC	distance	PC	n	m	distance	PC	n	m
7	nil	5	2	4	nil	5	3	4

```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
6
7  print(distance(2, 4)))
```

Recursion

PC	distance	PC	n	m	distance	PC	n	m
7	nil	5	2	4	nil	5	3	4

```
1  def distance(n,m):
2    if n >= m:
3      return 0
4    else:
5      return sum_between(n + 1, m) + 1
6
7  print(distance(2, 4)))
```

PC	distance	PC	n	m	distance	PC	n	m	distance	PC	n	m
7	nil	5	2	4	nil	5	3	4	nil	2	4	4

Recursion

PC	distance	PC	n	m	distance	PC	n	m	distance	PC	n	m
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2    if n >= m:
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7  print(distance(2, 4)))
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PC	distance
7	2

Assignments

Assignments

Build and test, on paper...

- A function `add` that increments a given number by a fixed value:
  - `add(1, 5)) -> 6`
- A function `isEven` that returns `True` if a given number is even, `False` otherwise:
  - `isEven(6) -> True`
- A function `sum_between` that returns the sum of all integers between two given integer numbers:
  - `sum_between(2,5) -> 14`

Conclusion

Conclusion

Lecture topics

- Often, user code needs to perform operations that are similar to each other
- Through the mechanism of function definition, we can recycle code
- Functions can encode algorithms in many way
  - Simple code abstractions to avoid repetition
  - Recursive problems

This is it!

The best of luck, and thanks for the attention!