Types

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Introduction

Lecture topics

- We introduce the Python type system
- Numbers
- Boolean values
- Arithmetic and boolean expressions

Introduction

- Is everything an integer number?
- Yes and no

Python type system basics

Everything is an integer number

- For the CPU everything is a string of bits
- So yes, everything is (*almost*[a]) an integer number
- Complex data structures like a GUI, a 3D model, a picture, etc. are made up of collections of numbers

[a] also floats are recognized by the CPU

Python type system basics

Everything is an integer number

- Low-level languages expose this view
- Everything is encoded with numbers
- It can become quite messy

Python type system basics

Not everything is an integer number

- For the programmer, there exist different kinds of values
- So common and useful that Python offers them out of the box
- Even if the CPU does not manipulate them directly

Python type system basics

Kinds of values

- Python has a **type system**
- Variables have different **data types**, often shortened to **types**
  - `Integer` numbers
  - Rational (`floating point`) numbers
  - `Boolean` truth values
  - `Strings` of text

Python type system basics

Integers

- Numbers without dot[a]
  - 0
  - 100
  - −500

[a] comma in Dutch

Python type system basics

Integers

- Typical arithmetic operations on numbers (**not in Python 3**)
  - `3 + 5 = 8`
  - `5 / 2 = 2`
  - `40 * 5 = 200`

Python type system basics

Floating points

- Numbers with dot[a]
  - `0.0`
  - `2.5`
  - `10.0e3`
  - `3.1e-5`
  - `-.1e-5`

[a] comma in Dutch

Python type system basics

The scientific notation

- `0.00001` is annoying to write
- we can write `1.e-4` instead
- the sign `e-N` means *add N zeros right after the dot*

Python type system basics

The scientific notation

- `1000000.0` is annoying to write
- we can write `1.e6` instead
- the sign `eN` means *add N zeros right before the dot*

Python type system basics

Floating points

- Typical arithmetic operations on numbers
  - `5.0 / 2.0 = ?`
  - `10.0e3 / 0.1 = ?`
  - `3.1e-5 + 1.0e5 = ?`
- **Can you guess the results?**

Python type system basics

Floating points

- Typical arithmetic operations on numbers
  - `5.0 / 2.0 = ?`
  - `10.0e3 / 0.1 = ?`
  - `3.1e-5 + 1.0e5 = ?`
- **Can you guess the results?**
  - `5.0 / 2.0 = 2.5`
  - `10.0e3 / 0.1 = 10.0e4`
  - `3.1e-5 + 1.0e5 = 100000.000031`

Python type system basics

Conversion to and from floating point

- Integers can be converted to floating points with `float(n)`
- Floating points can be converted to integers with `int(n)`

Python type system basics

Conversion to and from floating point

- Given the following expressions:
  - `int(2.5) = ?`
  - `float(3) = ?`
- **Can you guess the results?**

Python type system basics

Conversion to and from floating point

- Given the following expressions:
  - `int(2.5) = ?`
  - `float(3) = ?`
- **Can you guess the results?**
  - `int(2.5) = 2`
  - `float(3) = 3.0`

Python type system basics

Conversion to and from floating point

- Floating points can lose their decimal values
- They stay float's, but always end in `.0`
- `math.floor(n)` truncates the tail
- `math.ceil(n)` fills the tail and increases to the next unit

Python type system basics

Conversion to and from floating point

- Given the following expressions:
  - `floor(2.5) = ?`
  - `ceil(2.5) = ?`
- **Can you guess the results?**

Python type system basics

Conversion to and from floating point

- Given the following expressions:
  - `floor(2.5) = ?`
  - `ceil(2.5) = ?`
- **Can you guess the results?**
  - `floor(2.5) = 2.0`
  - `ceil(2.5) = 3.0`

Python type system basics

Conversion to and from floating point

- Some conversions happen automatically
- Python operations try to preserve information
- `5 / 2.0 = 2.5`, and `5` is converted to `5.0` right before the division

Python type system basics

Python 3 integer division

- The new version of Python has a new integer division: it always converts to float
- It is **very different** from most other programming languages
- `5 / 2 = 2.5`

Python type system basics

Python 3 integer division

- Traditional integer division is now "//"
- `5 // 2 = 2`

Python type system basics

Boolean values

- Truth values
- `True`, `False`
- "Answers to yes/no questions"

Python type system basics

Boolean values

- Logical operators on truth values
- Compose the asnwers to multiple questions
- Both questions in parallel:
  - Do you like chocolate? Yes.
  - Do you like vanilla? Yes.
  - **Do you like chocolate and vanilla? Yes.**
- Both questions concurrently:
  - Do you like chocolate? Yes.
  - Do you like vanilla? No.
  - **Do you like chocolate or vanilla? Yes.**
- Turn questions around:
  - Do you like chocolate? Yes.
  - **Do you dislike chocolate? No.**

Python type system basics

Boolean values

- Logical operators take one or two input
- This means that we have no more than four possible combinations of input values
- Since the inputs are so few, we can enumerate all combinations
- This is done with a **truth table**

Python type system basics

Boolean values

- Truth tables enumerate all input values and the result of their operator

A	B	(A $\odot$ B)
$True$	$True$	...
$True$	$False$	...
$False$	$True$	...
$False$	$False$	...

Python type system basics

Boolean values

- Logical operators on truth values
  - & for and

A	B	(A & B)
$True$	$True$	$True$
$True$	$False$	$False$
$False$	$True$	$False$
$False$	$False$	$False$

Python type system basics

Boolean values

- Logical operators on truth values
  - | for or

A	B	(A	|	B)
$True$	$True$	$True$	$True$	$True$
$True$	$False$	$True$	$True$	$False$
$False$	$True$	$False$	$True$	$True$
$False$	$False$	$False$	$False$	$Fasle$

Python type system basics

Boolean values

- Logical operators on truth values
  - `not`

A	*not*	A
True	*False*	*True*
False	*True*	*False*

Python type system basics

Boolean values

- Comparison operators on numeric values
  - >
  - <
  - ==
  - >=
  - <=

Python type system basics

Boolean values

- Given the following expressions:
  - `5.0 > 2.0 = ?`
  - `(3 > 4) | (5 == (3 + 2)) = ?`
  - `True & False = ?`
- **Can you guess the results?**

Python type system basics

Boolean values

- Given the following expressions:
  - `5.0 > 2.0 = ?`
  - `(3 > 4) | (5 == (3 + 2)) = ?`
  - `True & False = ?`
- **Can you guess the results?**
  - `5.0 > 2.0 = True`
  - `(3 > 4) | (5 == (3 + 2)) = True`
  - `True & False = False`

Python type system basics

String values

- Text
- `"Hello!"`, `"Hello world!"`, `""`, ...

Python type system basics

String values

- String literals are sequences of characters, on a single line, between double " or single ’ quotes
- Some characters do not fit this description
- We need special markings for such characters
- These special markings are called *escape characters*

Python type system basics

String values

- \' for single quote
- \" for double quote
- \a for ASCII Bell (BEL)
- \b for ASCII Backspace (BS)
- \f for ASCII Formfeed (FF)
- \n for ASCII Linefeed (LF)
- \r for ASCII Carriage Return (CR)
- \t for ASCII Horizontal Tab (TAB)
- \v for ASCII Vertical Tab (VT)

Python type system basics

String values

- `"Hello\n world"` is a string on two lines
- `"Hello\n world\n of Python"` is a string on three lines
- ...

Python type system basics

String values

- The most common operator is string concatenation
- `"Hello" + "\n" + "world" + "\n" + "on" + "\n" + "different" + "\n" + "lines"`

Type restrictions

Operations, types, and restrictions

- Not all operations are allowed on all possible variable types
  - Some operations are allowed (integer addition)
  - Some operations are not allowed (string division)
  - Some operations change meaning (addition of integers versus concatenation of strings)

Type restrictions

Operations, types, and restrictions

- Examples of allowed operators
  - Addition, subtraction, division, multiplication, etc. between numbers
  - Concatenation between strings
  - Multiplication of strings and integers
  - Arithmetic comparison between numbers or strings
  - Conjunction, disjunction, negation[a] between booleans
  - Treating integers as booleans (`1=True`, `0=False`)
  - Treating strings as booleans (anything else=`True`, `""=False`)

[a] `and`, `or`, `not`

Type restrictions

Operations, types, and restrictions

- Examples of not-allowed operators
  - Most arithmetic operations on strings and non-strings (`"Hello" + True`)
  - Most boolean operations on strings and non-strings (`"Hello" & True`)

Type errors

Not-allowed operators generate *type errors*

```
Traceback (most recent call last):
  File "C:\Users\Giuseppe\Desktop\DEV␣I␣samples\
      DEV_I_samples.py", line 8, in <module>
    print("Oh␣noes,␣a␣bug!" + 4)
TypeError: cannot concatenate 'str' and 'int'
    objects
```

Type restrictions

Operations, types, and restrictions

- Variables may change type in Python
- An integer variable becomes later on a string variable
- This is allowed, but dangerous
- A variable should never lose reasonable meaning
- Many type errors stem from *changes in meaning*, connected with *changes in type* of a variable

Operator precedence

Introduction

- Multiple operators in a single expression are ambiguous
- For example: `not True | True`
  - `(not True) | True = False | True = True`
  - `not (True | True) = not True = False`

Operator precedence

Introduction

- Python defines which operators are evaluated first, and which later
- Removes ambiguity
- Makes parentheses not required
  - Still, might remain better for readability

Operator precedence

Introduction

- From lowest precedence (least binding) to highest precedence (most binding)

Operator precedence

Introduction

- From lowest precedence (least binding) to highest precedence (most binding)
- Some operators share the same precedence
  - $+$, $-$
  - $*$, $/$

Operator precedence

Introduction

- From lowest precedence (least binding) to highest precedence (most binding)
- Some operators share the same precedence
  - $+$, $-$
  - $*$, $/$
- Unless the syntax is explicitly given (example by mean of parenthesis)

Operator precedence

Introduction

- From lowest precedence (least binding) to highest precedence (most binding)
- Some operators share the same precedence
  - $+$, $-$
  - $*$, $/$
- Unless the syntax is explicitly given (example by mean of parenthesis)
- A complete table of precedence can be found on `https://docs.python.org/2/reference/expressions.html#operator-precedence`

Operator precedence

Introduction

- Example: integer operations in Python like $*$ and $/$ have higher precedence than $+$ and $-$
- $1 + 4 * 2 = 9$

Operator precedence

Introduction

- Example: integer operations in Python like $*$ and $/$ have higher precedence than $+$ and $-$
- $1 + 4 * 2 = 9$
- Use parenthesis to group expressions
- $(1 + 4) * 2 = 10$

Operator precedence

Introduction

- Given the following expressions what are the results:
  - (20 + 10) * 15 / 5 = ?
  - ((20 + 10) * 15) / 5 = ?
  - 20 + (10 * 15) / 5 = ?

Operator precedence

Introduction

- Given the following expressions what are the results:
  - (20 + 10) * 15 / 5 = ?
  - ((20 + 10) * 15) / 5 = ?
  - 20 + (10 * 15) / 5 = ?
- Results:
  - (20 + 10) * 15 / 5 = 90
  - ((20 + 10) * 15) / 5 = 90
  - 20 + (10 * 15) / 5 = 50

Assignment

Instructions

- Split into four groups.
- Use the data types you saw in this lesson to model an RPG character in a Python program.
- Example: health, team color, ...
- Make sure the program runs without errors.
- Draw on a sheet what the soldier should look like.
- Hand over the code to another group and make them draw the soldier.
- If the pictures are the same then you have succeeded, otherwise adjust your code.

Assignment

Hand-in

- Write your names and student numbers on your sheets
- Hand them in
- *They may be used at your oral check* in the form of questions such as "how would you rewrite this after the course"

This is it!

The best of luck, and thanks for the attention!