Static Typing in Python

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About Me

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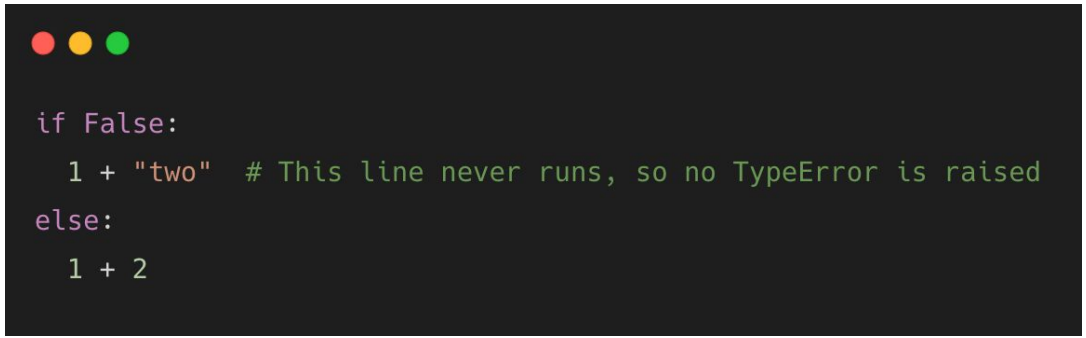
Setup

1. Clone the repo (https://github.com/alexmolas/python-static-typing)
2. Install a virtual environment with **python 3.12**
3. Install the requirements.txt

What's typing?

- **Dynamic typing**: Python is a dynamically typed language. This means it does type checking only as code runs, and that the type of a variable can change over its lifetime.

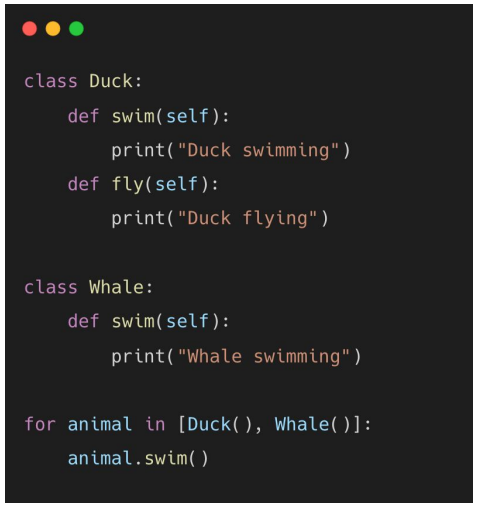


What's typing?

- **Static typing:** type checks are performed before running the program. Usually when the program is compiled.

What's typing?

- **Duck typing:** "if it walks like a duck and it quacks like a duck, then it must be a duck". This means that in Python you don't check the type of an object, you only check if it implements the methods that are needed.



```
class Duck:
    def swim(self):
        print("Duck swimming")
    def fly(self):
        print("Duck flying")

class Whale:
    def swim(self):
        print("Whale swimming")

for animal in [Duck(), Whale()]:
    animal.swim()
```

What's typing?

- **Dynamic typing**: Python is a dynamically typed language. This means it does type checking only as code runs, and that the type of a variable can change over its lifetime.
- **Static typing:** type checks are performed before running the program. Usually when the program is compiled.
- **Duck typing:** "if it walks like a duck and it quacks like a duck, then it must be a duck". This means that in Python you don't check the type of an object, you only check if it implements the methods that are needed.

Types in Python

Python has some builtin types

- *int*, *float*, *complex*, *list*, *tuple*, *range*, *bool*, *string*, *set*, *dict*, *etc.*

Python also allows you to define your own types via classes.

```
class Duck:
    def swim(self):
        print("Duck swimming")
    def fly(self):
        print("Duck flying")
```

Type Hinting

Even if Python is a **dynamically typed** language it allows for **type hints**.

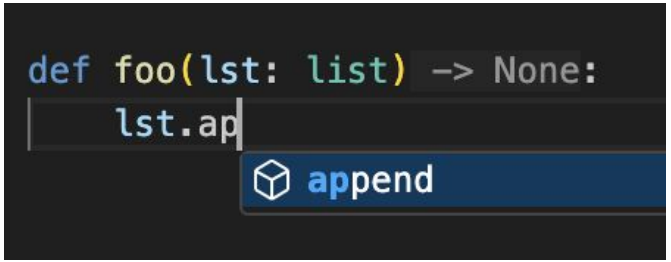
Type hinting consists in **annotating** variables, methods, function arguments, and return values with types.

```
def function(arg_1: type_1, arg_2: type_2 = default) -> return_type:
  ...

# example
def add(a: int, b: int = 2) -> int:
  return a + b
```

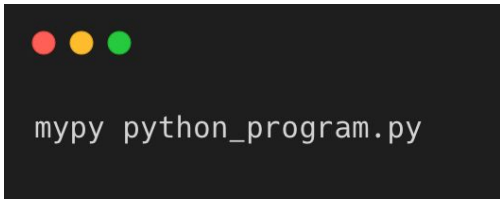
1st exercise!

1. Open **1.1-circumference-no-types.py**
2. Read it carefully.
3. Run it.
4. Add type hints.

Why are type hints useful?



- Type hint help the IDE to autofill or to recommend completions.
- Work as documentation. You know which type is supposed to be used.
- Can be used to type check your code. Check that types are consistent. Using **mypy**



2nd exercise

1. Open **2.1-headline-no-types.py** and read it.
2. Run **mypy** over **2.1-headline-no-types.py.** Since it doesn't have types no error is shown.
3. Execute **2.1-headline-no-types.py.** There are some errors 😱
4. Add types to **2.1-headline-no-types.py.**
5. Run again **mypy**. Does it show some error? Why?
6. Fix **2.1-headline-no-types.py**

Complex types

- Python allows you to type arguments with complex types.

```
list[TYPE]  # type the elements of a list. All the elements have the same type

tuple[TYPE1, TYPE2, etc]  # type the elements of a tuple. Can have different types

tuple[TYPE, ...]  # if it has multiple elements of the same type

dict[KEY_TYPE, VALUE_TYPE]  # to type dicts

int | float | str # union of different types
```

3rd exercise

1. Open **3.1-deck-game-no-types.py**
2. Read it and understand it.
3. Run it.
4. Add types.

Complex types: aliases

- To reduce verbosity we can use define our own types and type aliases

```
type Card = tuple[str, str]
type Deck = list[Card]

def create_deck(shuffle: bool = False) -> list[Card]:
  ...
```

4th exercise

1. Open **3.1-deck-game-no-types.py**
2. Define your own type aliases and reduce the verbosity of the code

Complex types: typing module

- There are some types that are not available in the builtins
- We can import them from the typing module
- For example we can type methods with *Callable[[input_types], output_type]*

```python
from typing import Callable, Sequence, Any

def select_first_element(x: Sequence[Any]) -> Any:
    # We use Sequence when we don't care if it's a list, tuple, string, etc
    # A Sequence contains items arranged in order and can be accesed by their index
    return x[0]

method: Callable[[Sequence[Any]], Any] = select_first_element
```

5th exercise

1. Open **4.1-process-data.py**
2. Read it and understand it.
3. Run it.
4. Add types.

Pydantic: how to type external data

- How to read a JSON and add type safety?
- Welcome to Pydantic!

```python
from pydantic import BaseModel
import json

class Student(BaseModel):
    name: str
    age: int

class Classroom(BaseModel):
    students: list[Student]

# data.json is
# {"students": [{"name": "John", "age": 19}, {"name": "Jane", "age": 25}]}

with open("data.json", "r") as f:
    json_data = json.load(f)
data = Classroom(**json_data)
```

Pydantic: complex validations

```python
class User(BaseModel):
    name: str
    email: str

    @field_validator("email")
    def validate_email(cls, v):
        if "@" not in v:
            raise ValueError("Email must contain @")
        return v
```

6th exercise

1. Open **5.1-json-no-types.py**
2. Read it and understand it.
3. Run it. Why is it failing?
4. Add types and Pydantic.

Generic

- Sometimes you want to type classes or method for generic types.
- Allow reuse of the same class with different type combinations.

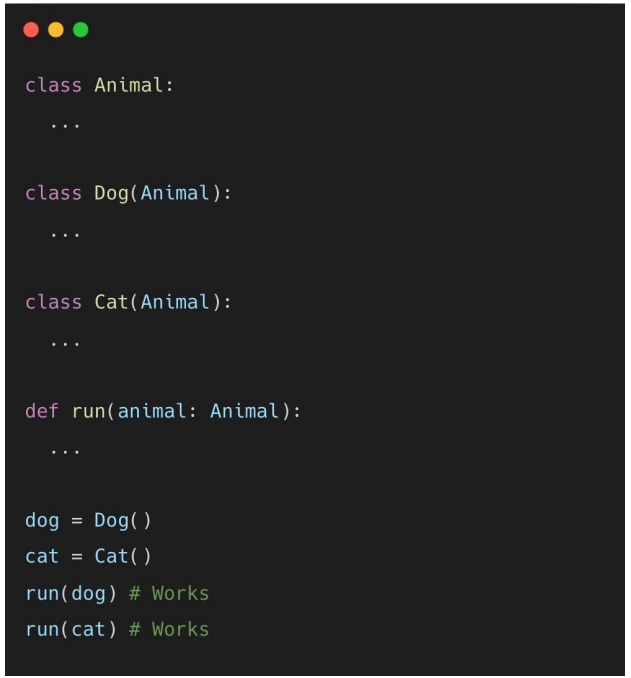
```
class GenericClass[K, V]:
  def get_value(self, key: K) -> V:
    ...

instance: GenericClass[int, str] = GenericClass()
```

7th exercise

1. Open **6.1-dict-no-types.py**
2. Read and understand it
3. Run it
4. Run mypy over it
5. What could go wrong?
6. Add types using generic

Your own types

You can define you own types using classes

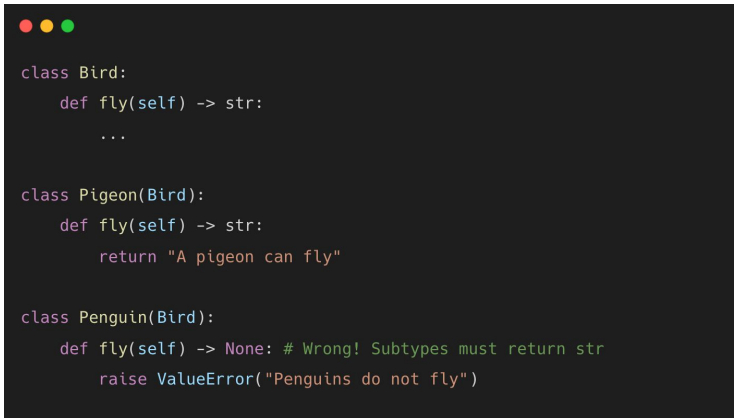


```python
class Animal:
  ...

class Dog(Animal):
  ...

class Cat(Animal):
  ...

def run(animal: Animal):
  ...

dog = Dog()
cat = Cat()
run(dog) # Works
run(cat) # Works
```

Your own types

Be careful of the Liskov substitution principle

> An object (such as a class) may be replaced by a sub-object (such as a class that extends the first class) without breaking the program



```python
class Bird:
    def fly(self) -> str:
        ...

class Pigeon(Bird):
    def fly(self) -> str:
        return "A pigeon can fly"

class Penguin(Bird):
    def fly(self) -> None: # Wrong! Subtypes must return str
        raise ValueError("Penguins do not fly")
```

8th exercise

1. Open and read **7.1-animals-types.py**
2. No need to do changes, just read it and enjoy it :)

More on duck typing: Protocols

- You can define structural subtypes.
- You don’t care about subclassing, just about implementing the needed methods.

```python
from typing import Protocol

class FlyingAnimal(Protocol):
  def fly(self) -> str:
    ...

class Pigeon:
  def fly(self) -> str:
    return "I'm a pigeon and I can fly"


class FlyingSquirrel:
  def fly(self) -> str:
    return "I'm a flying squirrel and I can fly"

def make_animal_fly(animal: FlyingAnimal):
  animal.fly()

make_animal_fly(Pigeon())
make_animal_fly(FlyingSquirrel())
```

Advanced examples

- In the folder *advanced* we have some advanced exercises.
- Play with them and have fun!

Conclusions

- We learned how to add type hints to python.
- Useful for code security, IDE completion, and documentation.
- mypy is a very useful tool to detect bugs in our code.
- Pydantic can help to add hints and data validation.
- Classes can be used as types.
- You can define structural subtypes using Protocols.

Q&A

If you have any doubt feel free to write me

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- Blog: www.alexmolas.com

Sources

- Basic examples:
  - https://realpython.com/python-type-checking/
- Advanced examples:
  - https://wickstrom.tech/2024-05-23-statically-typed-functional-programming-python-312.html