2025

Object Oriented Programming in Python

A refresh

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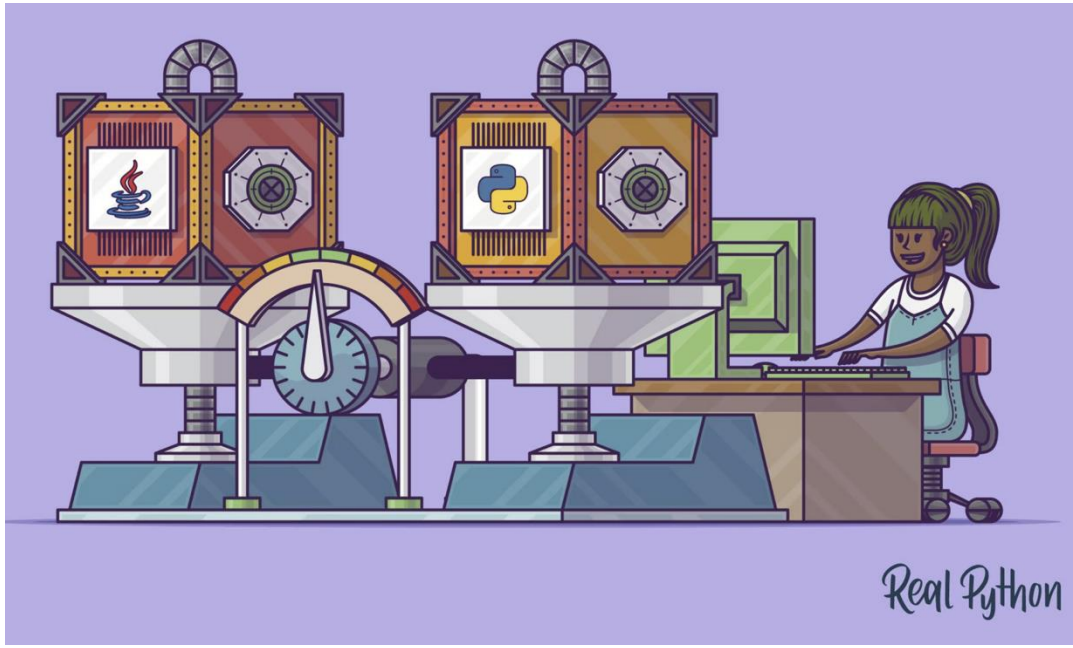


https://realpython.com/oop-in-python-vs-java/
https://realpython.com/python3-object-oriented-programming/

Known OOP features

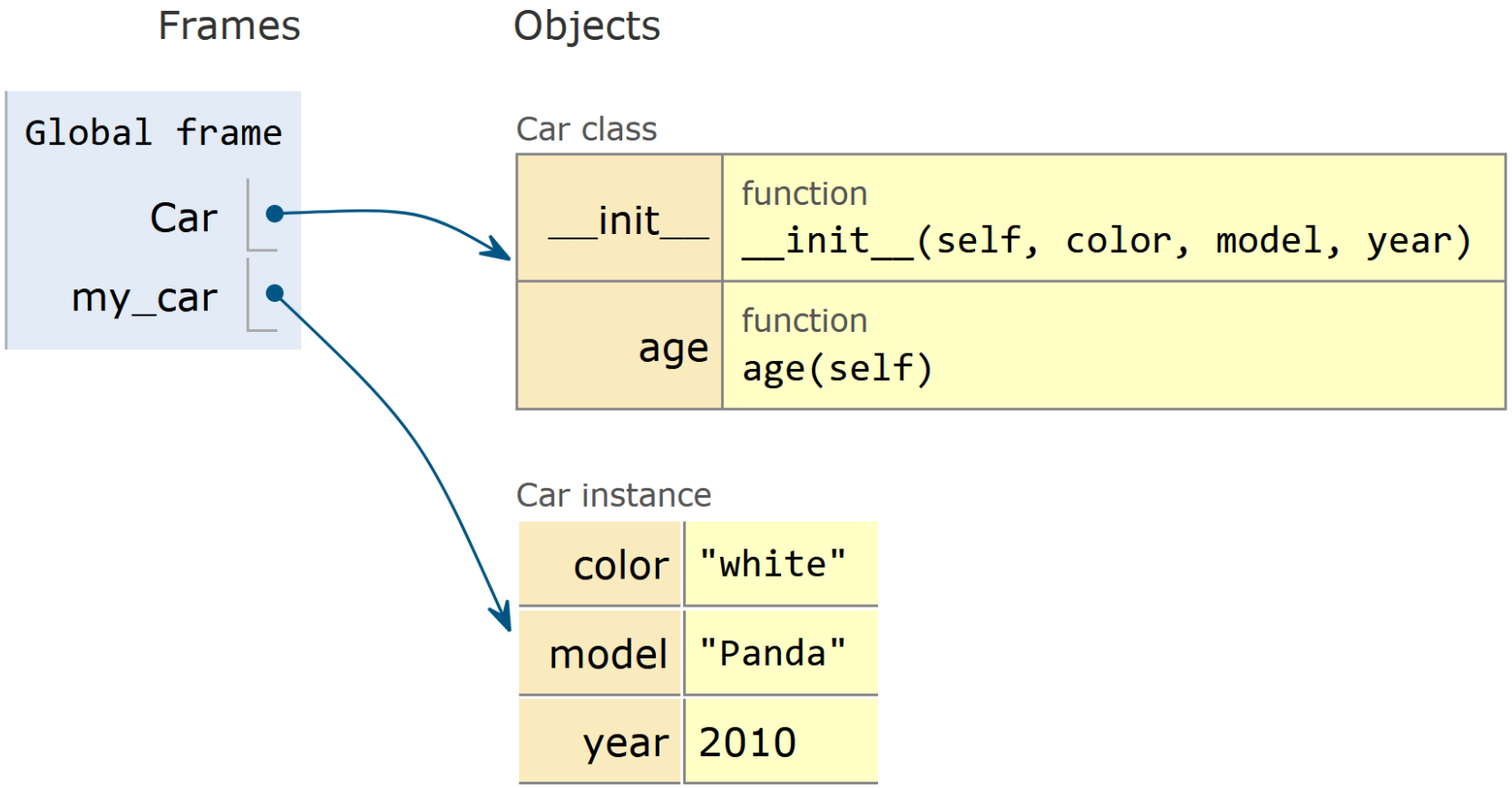
- Classes
- Objects
- Properties
- Methods
- Visibility
- Constructor
- Encapsulation
- Inheritance
- Abstraction
- Polymorphism
- Annotations
- Overloading

We assume these concepts are somewhat known, let’s see how they map in Python

Classes and Objects

```
class Car:
    def __init__(self, color, model, year):
        self.color = color
        self.model = model
        self.year = year

    def age(self):
        return 2024 - self.year

my_car = Car("white", "Panda", 2010)

print(my_car.age())
```

Visual representation



Classes and Objects

Class definition

```
class Car:
    def __init__(self, color, model, year):
        self.color = color
        self.model = model
        self.year = year

    def age(self):
        return 2024 - self.year

my_car = Car("white", "Panda", 2010)

print(my_car.age())
```

Method definition

Instance

"new"

Method call

Classes and Objects

```
class Car:
    def __init__(self, color, model, year):
        self.color = color
        self.model = model
        self.year = year

    def age(self):
        return 2024 - self.year

my_car = Car("white", "Panda", 2010)

print(my_car.age())
```

Constructor

Constructor parameters

"new"

Constructor arguments

Classes and Objects

```
class Car:
    def __init__(self, color, model, year):
        self.color = color
        self.model = model
        self.year = year

    def age(self):
        return 2024 - self.year

my_car = Car("white", "Panda", 2010)

print(my_car.age())
```

Properties

Classes and Objects

```
class Car:                    "this"
    def __init__(self, color, model, year):
        self.color = color
        self.model = model
        self.year = year
                  "this"
    def age(self):          "this"
        return 2024 - self.year

my_car = Car("white", "Panda", 2010)
         "this"
print(my_car.age())
```

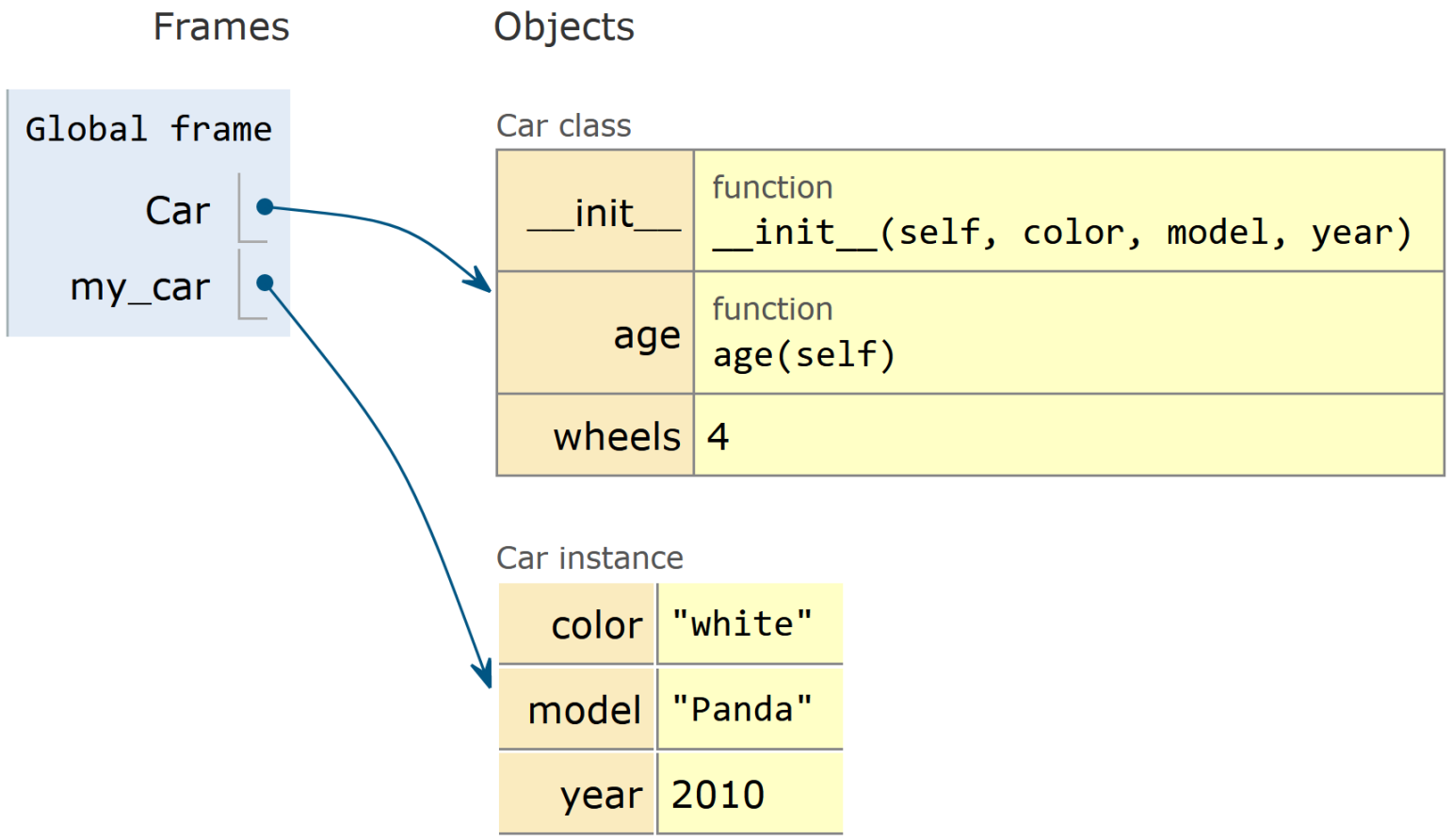
What is '`self`'?

- Each method receives, as a first argument, the reference to the object instance
- By convention, this parameter is called `self`
- Upon calling a method, `self` is initialized with the reference to the instance
- `my_car.age()` sets `self` to `my_car`
  - Equivalent to `Car.age(my_car)` (static method call with explicit self)
- Using **`self`** is always mandatory (unlike `this`, that can be omitted)

Class attributes vs. instance attributes

```
class Car:
    wheels = 4  # class attribute (‘static’ in Java)

    def __init__(self, color, model, year):
        self.color = color  # instance attribute
        self.model = model
        self.year = year

print(Car.wheels)
print(my_car.wheels) # instances may access class attributes
```

Class attributes vs. instance attributes



Dynamic nature of attributes

- Instance attributes are normally defined in the `__init__` constructor
  - All instances will have the same set of attributes
  - Their value may be redefined in methods (`self.`*`name`*) or in external code (`my_car.`*`name`*)
- However, new attributes may be created later
  - In any instance method (just assign a value to `self.`*`new_name`*)
  - In the external code (just assign a value to `my_car.`*`new_name`*)
  - Such attribute is assigned to the specific instance, only
  - Works also for class-level attributes (`Car.`*`new_name`*)
  - Try to avoid this possibility, as it renders the code much less readable

Getters and Setters? No, thanks

- In Java, object properties (= instance attributes) are normally defined with a private visibility, and are not accessible from outside the class methods
  - `get`*`Xxx`*`()` and `set`*`Xxx`*`(`*`xxx`*`)` methods must be defined, for each property *xxx*
- In Python, attributes are always visible, and no getter/setters are required
  - Just read/write the attribute value

Visibility conventions

- All class-level attributes and instance-level attributes are **public**
- By convention, if you consider an attribute to be “private”, prefix it with one or two “_” (underscore)
- `self.counter`
  - may be accessed (read/written) by anyone
- `self._counter`
  - may still be accessed by anyone, but it’s not polite to do that, and your IDE may send you a warning. You should consider it a private value
- `self.__counter` (*two* underscores)
  - it is difficult to access if you are outside a method (Python will mangle its name to _ClassName__counter), so you will not access it by mistake (unless you really really want)

Getters and Setters, if/when you want them

- Need to customize what happens when you read/write a ‘private’ attribute?
- Use the `@property` annotation
- `@property` for the getter method
- `@name.setter` for the setter method
  - If omitted, it will be read-only
- Both methods have the *name* of the property

```python
class Car:
    def __init__(self, color, model, year):
        self.color = color
        self.model = model
        self.year = year
        self._voltage = 12

    @property
    def voltage(self):
        return self._voltage

    @voltage.setter
    def voltage(self, volts):
        print("Warning: this can cause problems!")
        self._voltage = volts
```

Special methods

- All objects can customize their behavior in implicit and arithmetic operators, by defining special methods
- Such methods have all a double-underscore at the beginning & end of the name
- Hence, the definition of "*dunder*" (double underscore) methods
- Example: `__init__(self, …)` # pronounced: *dunder-init*

  – Full list of *dunder* methods: https://docs.python.org/3/reference/datamodel.html#special-method-names

Dunder methods: convert to string

- `__str__(self)`
  - string printable representation (like toString())
- `__repr__(self)`
  - programmer-oriented printable representation (usually, the object creation)

```
class Car:
    # ...

    def __str__(self):
        return f"{self.make}, {self.model}, {self.color}: ({self.year})"

    def __repr__(self):
        return (
            f"{type(self).__name__}"
            f'(make="{self.make}", '
            f'model="{self.model}", '
            f"year={self.year}, "
            f'color="{self.color}")'
        )
```

```
>>> toyota_camry = Car("Toyota", "Camry", 2022, "Red")

>>> str(toyota_camry)
'Toyota, Camry, Red: (2022)'
>>> print(toyota_camry)
Toyota, Camry, Red: (2022)

>>> toyota_camry
Car(make="Toyota", model="Camry", year=2022, color="Red")
>>> repr(toyota_camry)
'Car(make="Toyota", model="Camry", year=2022, color="Red")'
```

Dunder methods: comparisons

- `__eq__(self, other)`
  - implements `==` operator
  - Replaces Java's .equal()
- `__lt__(self, other)`
  - Implements `<` operator
  - Replaces Java's Comparator, Comparable, compare(), compareTo()
- Other operators (>, <=, !=, >=) are inferred from these methods
- All data structures (dictionaries, sets, …) and methods (sort, max, index, …) honor these operators

Dunder methods: operators overloading

- `object.__add__(self, other)`
- `object.__sub__(self, other)`
- `object.__mul__(self, other)`
- `object.__matmul__(self, other)`
- `object.__truediv__(self, other)`
- `object.__floordiv__(self, other)`
- `object.__mod__(self, other)`
- `object.__divmod__(self, other)`
- `object.__pow__(self, other[, modulo])`
- `object.__lshift__(self, other)`
- `object.__rshift__(self, other)`
- `object.__and__(self, other)`
- `object.__xor__(self, other)`
- `object.__or__(self, other)`

- `object.__neg__(self)`
- `object.__pos__(self)`
- `object.__abs__(self)`
- `object.__invert__(self)`

- `object.__complex__(self)`
- `object.__int__(self)`
- `object.__float__(self)`

- `object.__radd__(self, other)`
- `object.__rsub__(self, other)`
- `object.__rmul__(self, other)`
- `object.__rmatmul__(self, other)`
- `object.__rtruediv__(self, other)`
- `object.__rfloordiv__(self, other)`
- `object.__rmod__(self, other)`
- `object.__rdivmod__(self, other)`
- `object.__rpow__(self, other[, modulo])`
- `object.__rlshift__(self, other)`
- `object.__rrshift__(self, other)`
- `object.__rand__(self, other)`
- `object.__rxor__(self, other)`
- `object.__ror__(self, other)`

- `object.__round__(self[, ndigits])`
- `object.__trunc__(self)`
- `object.__floor__(self)`
- `object.__ceil__(self)`

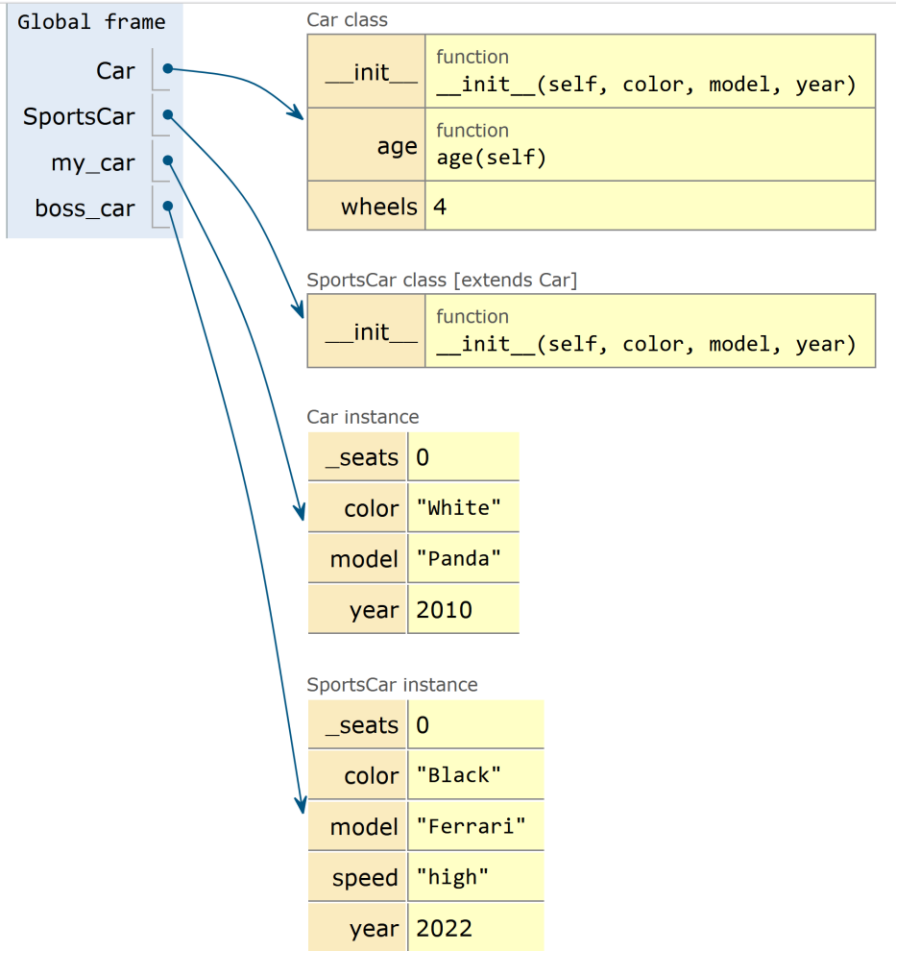
- `object.__index__(self)`

Inheritance

- A class may inherit from another class
  - `class SportsCar(Car):`
- All attributes and methods are inherited
- Must call parent class' __init__ method
  -
```
def __init__(self):
    Car.__init__()   # or: super().__init__()
    self.speed = 'high'
```

Example

```python
class Car:

    wheels = 4

    def __init__(self, color, model, year):
        self.color = color
        self.model = model
        self.year = year
        self._seats = 0

    def age(self):
        return 2024 - self.year

class SportsCar(Car):
    def __init__(self, color, model, year):
        super().__init__(color, model, year)
        self.speed = 'high'

my_car = Car('White', 'Panda', 2010)
boss_car = SportsCar('Black', 'Ferrari', 2022)
```



Multiple Inheritance

- In Python, it's possible for a class to inherit from more than one superclass:
  - `class SportsCar(Car, ExpensiveGadget):`
- All attributes and methods for both superclasses are imported, in the order of declaration
- Must call **both** constructors, `Car.__init__()` and `ExpensiveGadget.__init__()`

- There are **no** 'interfaces' in Python, thanks to multiple inheritance

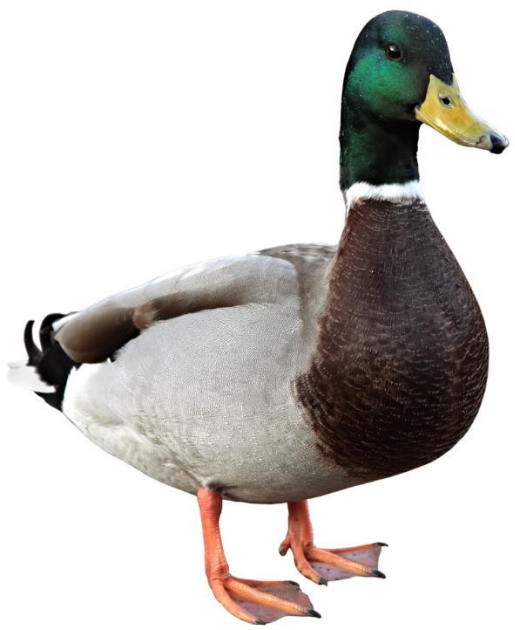
Polymorphism

- Polymorphism = calling the same method / function / operation, with different data types
- Java examples:
  - With sub-classes: `public double area(Polygon p)`, called with an object of type `Rectangle`, which is a sub-class of `Polygon`, or implements a `Polygon` interface
  - With overloaded methods: `public double area(Polygon p)` and `public double area(Conic c)`
- Java selects which method to call based on the signature of the methods and of the inheritance relationships

Polymorphism in Python

- In Python, method parameters don't have a type specification: cannot check for subclasses or signatures
- Python uses a strategy called "Duck Typing"

> "If it walks like a duck and it quacks like a duck, then it must be a duck"



Duck typing

- The type or the class of an object is less important than the methods it defines
- When you use duck typing, you do not check types at all. Instead, you check for the presence of a given method or attribute

Example (1)

```
def pretty_print(data_provider):
    data = data_provider.read_data()
    for d in data:
        print(d[0])
```

What is the allowed type of `data_provider`?

Duck typing says: any class that has a `read_data` method.

The function may be called with totally different classes as parameters

```
source_database = DatabaseAccess('localhost', 'root', 'root', 'data')
pretty_print(source_database)


source_file = FileAccess('data.csv')
pretty_print(source_file)
```

Example (2)

```
class DatabaseAccess():
    def __init__(self, server, username, password, database):
        self.connection = mysql.connector.connect(server, username, password, database)

    def read_data(self):
        cursor = self.connection.cursor()
        cursor.execute('SELECT * FROM numbers')
        result = cursor.fetchall()
        return result
```

```
class FileAccess():
    def __init__(self, file_name):
        self.file_name = file_name

    def read_data(self):
        with open(self.file_name, 'r') as f:
            lines = f.readlines()
        result = []
        for line in lines:
            result.append(line.rstrip().split(','))
        return result
```

Two unrelated classes, both implementing a read_data method, are interchangeable in pretty_print.

Polymorphism

- Inside a polymorphic function, you may check the classes of the received instances. Useful to avoid errors before calling methods that might not exist.
- Do not abuse, it defeats the simplicity of Duck Typing

isinstance(*object*, *classinfo*)

Return `True` if the *object* argument is an instance of the *classinfo* argument, or of a (direct, indirect, or virtual) subclass thereof. If *object* is not an object of the given type, the function always returns `False`. If *classinfo* is a tuple of type objects (or recursively, other such tuples) or a Union Type of multiple types, return `True` if *object* is an instance of any of the types. If *classinfo* is not a type or tuple of types and such tuples, a `TypeError` exception is raised. `TypeError` may not be raised for an invalid type if an earlier check succeeds.

Protocols

- Many built-in functions, operators, and keywords are polymorphic
- The set of required methods is called "protocol"
- Examples:
  - The `len()` function accepts any object with a `__len__()` method
  - Any object can be iterated if it has a `__iter__()` method
  - An object can be indexed if it has a `__getitem__()` method
  - An object may be used in the `with` statement if it implements an `__enter__()` and an `__exit__()` method

https://mypy.readthedocs.io/en/stable/protocols.html#predefined-protocol-reference

A Well-Defined class

- To correctly interoperate in the Python world, your class must define
  - An `__init__()` method
  - A set of `self.name` instance attributes initialized in the `__init__()` method
  - A `__repr__()` method for conversion to a (programmer-oriented) string
  - An `__eq__()` method for allowing == and != comparisons
  - If required, ordering methods such as `__le__()` for allowing < > <= >= comparisons
  - A `__hash__()` method to be used by sets and dict keys
  - If required, setter/getter methods for attributes

Boilerplate code

  - Plus any other methods specifying its behavior

Dataclasses

- The “boilerplate” code can be automatically generated by the `@dataclass` decorator
  - Especially useful for classes with basic behavior, such as “data container” classes

Python

```
class RegularCard:
    def __init__(self, rank, suit):
        self.rank = rank
        self.suit = suit
```

…plus boilerplate dunder methods

Python

```
from dataclasses import dataclass

@dataclass
class DataClassCard:
    rank: str
    suit: str
```

- `@dataclass` decorator
- List of attributes
- Expected types of attributes, after colon

https://docs.python.org/3/library/dataclasses.html
https://realpython.com/python-data-classes/

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