Programming Principles in Python (CSCI 503)

Object-Oriented Programming

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Arrays

- Usually a fixed size—lists are meant to change size
- Are mutable—tuples are not
- Store only one type of data—lists and tuples can store anything
- Are faster to access and manipulate than lists or tuples
- Can be multidimensional:
  - Can have list of lists or tuple of tuples but no guarantee on shape
  - Multidimensional arrays are rectangles, cubes, etc.

NumPy Arrays

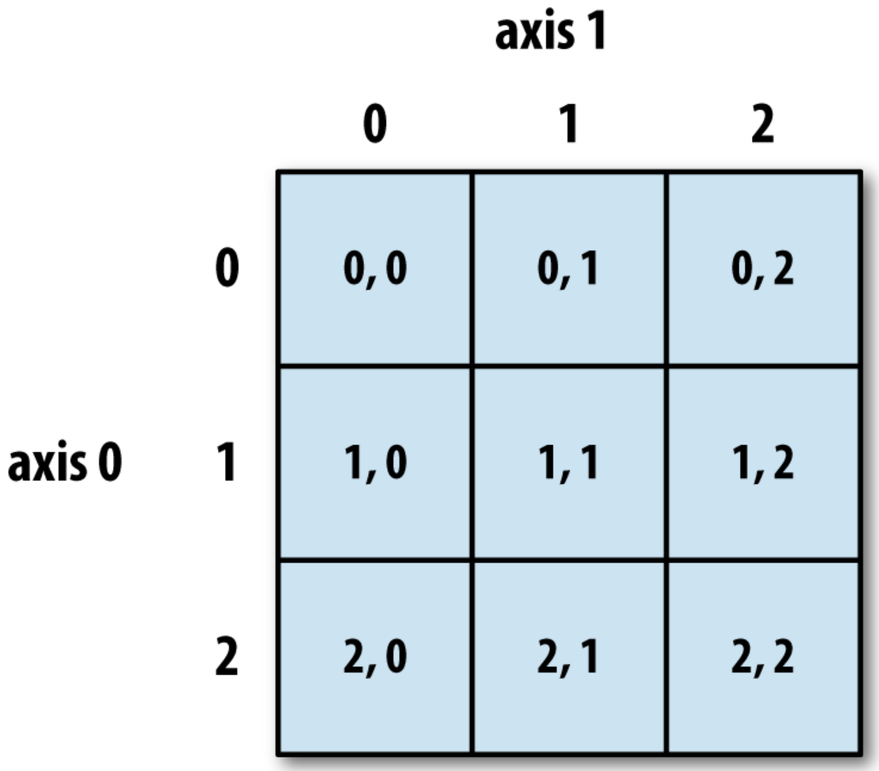
- import numpy as np
- Creating:
  - `data1 = [6, 7, 8, 0, 1]`
  - `arr1 = np.array(data1)`
  - `arr1_float = np.array(data1, dtype='float64')`
  - `np.ones((4,2)) # 2d array of ones`
  - `arr1_ones = np.ones_like(arr1) # [1, 1, 1, 1, 1]`
- Type and Shape Information:
  - `arr1.dtype # int64 # type of values stored in array`
  - `arr1.ndim # 1 # number of dimensions`
  - `arr1.shape # (5,) # shape of the array`

Array Operations

- ```
  a = np.array([1,2,3])
  b = np.array([6,4,3])
  ```
- (Array, Array) Operations (**Element-wise**)
  - Addition, Subtraction, Multiplication
  - `a + b # array([7, 6, 6])`
- (Scalar, Array) Operations (**Broadcasting**):
  - Addition, Subtraction, Multiplication, Division, Exponentiation
  - `a ** 2 # array([1, 4, 9])`
  - `b + 3 # array([9, 7, 6])`
  ```

Indexing

- Same as with lists
  - `arr1 = np.array([6, 7, 8, 0, 1])`
  - `arr1[1]`
  - `arr1[-1]`
- What about two dimensions?
  -
```
arr2 = np.array([[1,2,3],
                 [4,5,6],
                 [7,8,9]])
```
  - `arr[1][1]`
  - `arr[1,1] # shorthand`



Slicing

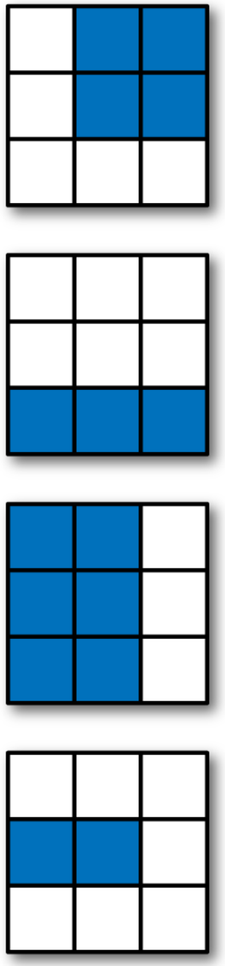
- 1D: Similar to lists
  - `arr1 = np.array([6, 7, 8, 0, 1])`
  - `arr1[2:5] # np.array([8,0,1]), sort of`
- Can **mutate** original array:
  - `arr1[2:5] = 3 # supports assignment`
- Slicing returns **views** (copy the array if original array shouldn't change)
  - `arr1.copy()` or `arr1[2:5].copy()` will copy

Assignment 5

- Scripts and Modules
- Write a three modules in a Python package with methods to process Pokémon data
- Write a script to retrieve Pokémon information via command-line arguments
- MaxCP formula fixed by 2021-02-28
- Turn in a zip file with package
- No notebook required, but useful to test your code as you work
  - `%autoreload` or `importlib.reload`

2D Array Slicing

How to obtain the blue slice from array `arr`?



[W. McKinney, Python for Data Analysis]

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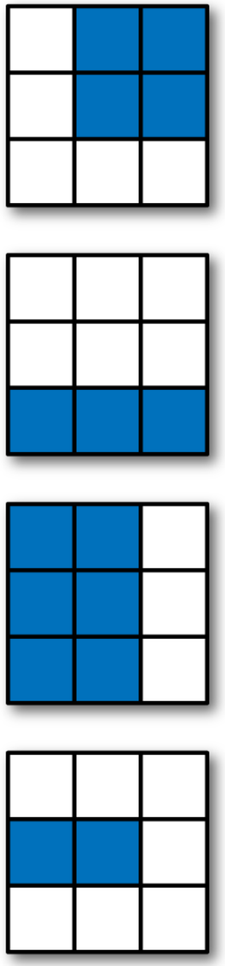

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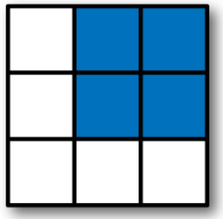

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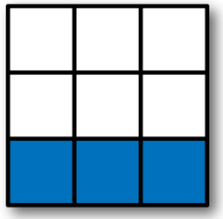
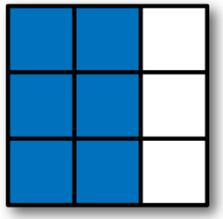
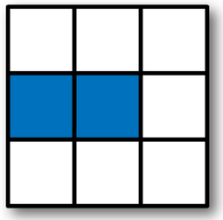


Expression	Shape
`arr[2]`	`(3,)`
`arr[2, :]`	`(3,)`
`arr[2:, :]`	`(1, 3)`





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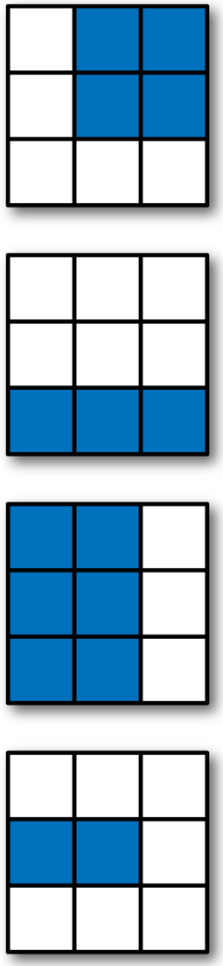

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`arr[:, :2]`	`(3, 2)`

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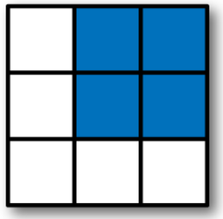

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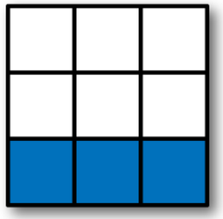

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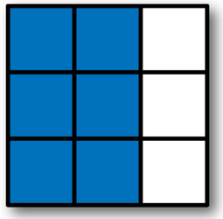

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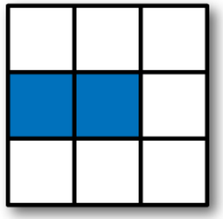
`arr[:, :2]`	`(3, 2)`



Expression	Shape
`arr[1, :2]`	`(2,)`
`arr[1:2, :2]`	`(1, 2)`

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Slicing

- 2D+: comma separated indices as shorthand:
  - `arr2 = np.array([[1.5,2,3,4],[5,6,7,8]])`
  - `a[1:2,1:3]`
  - `a[1:2,:] # works like in single-dimensional lists`
- Can combine index and slice in different dimensions
  - `a[1,:] # gives a row`
  - `a[:,1] # gives a column`
- Slicing vs. indexing produces different shapes!
  - `a[1,:] # 1-dimensional`
  - `a[1:2,:] # 2-dimensional`

More Reshaping

- reshape:
  - `arr2.reshape(4,2) # returns new view`
- resize:
  - `arr2.resize(4,2) # no return, modifies arr2 in place`
- flatten:
  - `arr2.flatten() # array([1.5,2.,3.,4.,5.,6.,7.,8.])`
- ravel:
  - `arr2.ravel() # array([1.5,2.,3.,4.,5.,6.,7.,8.])`
- flatten and ravel look the same, but ravel is a **view**

Array Transformations

- Transpose
  - `arr2.T # flip rows and columns`
- Stacking: take iterable of arrays and stack them horizontally/vertically
  - `arrh1 = np.arange(3)`
  - `arrh2 = np.arange(3,6)`
  - `np.vstack([arrh1, arrh2])`
  - `np.hstack([arr1.T, arr2.T]) # ???`

Boolean Indexing

- `names == 'Bob'` gives back booleans that represent the element-wise comparison with the array `names`
- Boolean arrays can be used to index into another array:
  - `data[names == 'Bob']`
- Can even mix and match with integer slicing
- Can do boolean operations (`&`, `|`) between arrays (just like addition, subtraction)
  - `data[(names == 'Bob') | (names == 'Will')]`
- Note: `or` and `and` do not work with arrays
- We can set values too! `data[data < 0] = 0`

Object-Oriented Programming

Object-Oriented Programming Concepts

- ?

Object-Oriented Programming Concepts

- Abstraction: simplify, hide implementation details, don't repeat yourself
- Encapsulation: represent an entity fully, keep attributes and methods together
- Inheritance: reuse (don't reinvent the wheel), specialization
- Polymorphism: methods are handled by a single interface with different implementations (overriding)

Object-Oriented Programming Concepts

- **Abstraction**: simplify, hide implementation details, don't repeat yourself
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Vehicle Example

- Suppose we are implementing a city simulation, and want to model vehicles driving on the road
- How do we represent a vehicle?
  - Information (attributes)
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Vehicle Example

- Suppose we are implementing a city simulation, and want to model vehicles driving on the road
- How do we represent a vehicle?
  - Information (attributes): make, model, year, color, num_doors, engine_type, mileage, acceleration, top_speed, braking_speed
  - Methods (actions): compute_estimated_value(), drive(num_seconds, acceleration), turn_left(), turn_right(), change_lane(dir), brake(), check_collision(other_vehicle)

Other Entities

- Road, Person, Building, ParkingLot
- Some of these interact with a Vehicle, some don't
- We want to store information associated with entities in a structured way
  - Building probably won't store anything about cars
  - Road should not store each car's make/model
  - …but we may have an association where a Road object keeps track of the cars currently driving on it

Object-Oriented Design

- There is a lot more than can be said about how to best define classes and the relationship between different classes
- It's not easy to do this well!
- Software Engineering
- Entity Relationship (ER) Diagrams
- Difference between Object-Oriented Model and ER Model

Class vs. Instance

- A **class** is a blueprint for creating instances
  - e.g. Vehicle
- An **instance** is an single object created from a class
  - e.g. 2000 Red Toyota Camry
  - Each object has its own attributes
  - Instance methods produce results unique to each particular instance

Classes and Instances in Python

- Class Definition:
  -
```
class Vehicle:
    def __init__(self, make, model, year, color):
        self.make = make
        self.model = model
        self.year = year
        self.color = color

    def age(self):
        return 2021 - self.year
```
- Instances:
  -
```
car1 = Vehicle('Toyota', 'Camry', 2000, 'red')
```
  -
```
car2 = Vehicle('Dodge', 'Caravan', 2015, 'gray')
```

Constructor

- How an object is created and initialized
  -
```
def __init__(self, make, model, year, color):
    self.make = make
    self.model = model
    self.year = year
    self.color = color
```
- `__init__` denotes the **constructor**
  - Not required, but usually should have one
  - All initialization should be done by the constructor
  - There is only **one** constructor allowed
  - Can add defaults to the constructor (`year=2021, color='gray'`)

Instance Attributes

- Where information about an object is stored
  -
```
def __init__(self, make, model, year, color):
    self.make = make
    self.model = model
    self.year = year
    self.color = color
```
- `self` is the current object
- `self.make`, `self.model`, `self.year`, `self.color` are **instance attributes**
- There is **no declaration** required for instance attributes like in Java or C++
  - Can be created in any instance method…
  - …but good OOP design means they should be initialized in the constructor

Instance Methods

- Define actions for instances

```
- def age(self):
      return 2021 - self.year
```

- Like constructors, have self as first argument
- `self` will be the object calling the method
- Have access to instance attributes and methods via `self`
- Otherwise works like a normal function
- Can also modify instances in instance methods:

```
- def set_age(self, age):
      self.year = 2021 - age
```

Creating and Using Instances

- Creating instances:
  - Constructor expressions specify the name of the class to instantiate and specify any arguments to the constructor (not including `self`)
  - Returns new object
  - `car1 = Vehicle('Toyota', 'Camry', 2000, 'red')`
  - `car2 = Vehicle('Dodge', 'Caravan', 2015, 'gray')`
- Calling an instance method
  - `car1.age()`
  - `car1.set_age(20)`
  - Note `self` is not passed explicitly, it's `car1` (instance before the dot)

Used Objects Many Times Before

- Everything in Python is an object!
  - `my_list = list()`
  - `my_list.append(3)`
  - `num = int('64')`
  - `name = "Gerald"`
  - `name.upper()`

Visibility

- In some languages, encapsulation allows certain attributes and methods to be hidden from those using an instance
- public (visible/available) vs. private (internal only)
- Python does not have visibility descriptors, but rather conventions (PEP8)
  - Attributes & methods with a leading underscore (_) are intended as private
  - Others are public
  - You can still access private names if you want but generally **shouldn't**:
    - `print(car1._color_hex)`
  - Double underscores leads to **name mangling**:
    `self.__internal_vin` is stored at `self._Vehicle__internal_vin`

Representation methods

- Printing objects:
  - `print(car1) # <__main__.Vehicle object at 0x7efc087c6b20>`
- "Dunder-methods": `__init__`
- Two for representing objects:
  - `__str__`: human-readable
  - `__repr__`: official, machine-readable
-
```
>>> now = datetime.datetime.now()
>>> now.__str__()
'2020-12-27 22:28:00.324317'
>>> now.__repr__()
'datetime.datetime(2020, 12, 27, 22, 28, 0, 324317)'
```

[https://www.journaldev.com/22460/python-str-repr-functions]

Representation methods

- Car example:
  - `class Vehicle:`

```
        …
        def __str__(self):
            return f'{self.year} {self.make} {self.model}'
```

- Don't call `print` in this method! Return a string
- When using, don't call directly, use `str` or `repr`
  - `str(car1)`
- `print` internally calls `__str__`
  - `print(car1)`

Other Dunder Methods

- `__eq__(<other>)`: return `True` if two objects are equal
- `__lt__(<other>)`: return `True` if object < other
- Collections:
  - `__len__()`: return number of items
  - `__contains__(item)`: return `True` if collection contains `item`
  - `__getitem__(index)`: return item at `index` (which could be a key)
- + More

Properties

- Common pattern is getters and setters:

```
- def age(self):
      return 2021 - self.year
- def set_age(self, age):
      self.year = 2021 - age
```

- In some sense, this is no different than year except that we don't want to store `age` separate from `year` (they should be linked)
- Properties allow transformations and checks but are accessed like attributes
-
```
@property
def age(self):
    return 2021 - self.year
```

- `car1.age # 21`

Properties

- Can also define setters
- Syntax is a bit strange, want to link the two: `@<property-name>.setter`
- Method has the same name as the property: How?
- Decorators (`@<decorator-name>`) do some magic
- ```
  @property
  def age(self):
      return 2021 - self.year
  ```
- ```
  @age.setter
  def age(self, age):
      self.year = 2021 - age
  ```
- `car1.age = 20`

Properties

- Add validity checks!
- First car was 1885 so let's not allow ages greater than that (or negative ages)
- ```
  @age.setter
  def age(self, age):
      if age < 0 or age > 2021 - 1885:
          print("Invalid age, will not set")
      else:
          self.year = 2021 - age
  ```
- Better: raise exception (later)
  ```

Class Attributes

- We can add class attributes inside the class indentation:
- Access by prefixing with **class name** or `self`

```
- class Vehicle:
      CURRENT_YEAR = 2021
      …
      @age.setter
      def age(self, age):
          if age < 0 or age > Vehicle.CURRENT_YEAR - 1885:
              print("Invalid age, will not set")
          else:
              self.year = self.CURRENT_YEAR - age
```

- Constants should be CAPITALIZED
- This is not a great constant! (`EARLIEST_YEAR = 1885` would be!)