Data Structures and Algorithms

Live Class 7

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Today

1. **The list and related data structures**
2. Object-oriented programming (OOP)

Data structures

How to organise data for quick access?

- Like with algorithms: recipe → translate to Python

Examples: lists, stacks, queues, dictionaries (hash tables), graphs, trees, etc

Different data structures are suitable for different tasks

- Support different sets of operations (`list` vs `dict`)
- How to choose?

List operations complexity?

```
L = [1, 1999, 0, -2, 9]
L.append(9)
t = L[2]
t = L.pop(0)
```

We have **assumed** that list operations like retrieving or adding an item are $O(1)$

- A list has internal functions with algorithms to perform these operations

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But we have seen that **how we write algorithms matters** a lot...

- Does it matter how you implement a list?
- Yes!
- What is the internal data representation of a list?

How can we implement a list?

For a list, we would like to:

- Add and remove elements, look up values, change values, ...

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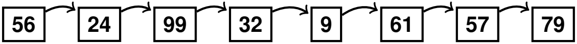
- Easy to access an item at index `i`: $O(1)$
- Easy to add an item to end: $O(1)$ (but details are advanced...)
- **Difficult to add item to beginning**: $O(n)$ (need to move all other elements)

A linked list of “nodes”?

Linked list?



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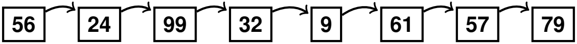

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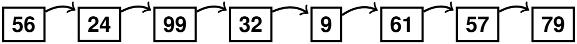
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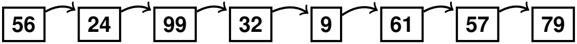

- **Each node contains information on the next node** – the list itself just knows the first and last one
- Easy to add items to either end: $O(1)$
- **Difficult to look up item by index**... $O(n)$ (need to walk through the nodes)

Today

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2. **Object-oriented programming (OOP)**

We have already been using data structures

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'Hello World'
3.14159
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These are all **objects**. An object has:

- A type: `int`, `str`, `list` (`L` is an **instance** of a `list`)
- An internal representation of data
- A set of functions that operate on that data (methods)

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An object bundles data and relevant actions

A Python list has many operations

`len(L),max(L),min(L),...`

`L[start:stop:step]`: returns elements of `L` from `start` to `stop` with step size `step`

`L[i]= e`: sets the value at index `i` to `e`

`L.append(e)`: adds `e` to the end of `L`

`L.count(e)`: returns how many times `e` occurs in `L`

`L.insert(i, e)`: inserts `e` at index `i` of `L`

`L.extend(L1)`: appends the items of `L1` to the end of `L`

`L.remove(e)`: deletes the first occurrence of `e` from `L`

`L.index(e)`: returns the index of first occurrence of `e` in `L`

`L.pop(i)`: removes and returns the item at index `i`, default `i = -1`

`L.sort()`: sorts elements of `L`

`L.reverse()`: reverses the order of elements of `L`

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```
L = [1, 1999, 0, -2, 9]
L.append(8)
L.insert(2, 1000)
t = L.pop()
L.remove(1)
help(L)
```

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An object bundles data and actions

```python
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L.append(8)
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t = L.pop()
L.remove(1)
help(L)
```

The point:

- Interface: the user knows what she can do with a list
- Abstraction: the user does not need to know the details of what goes on under the hood (similarly to functions)
- Invaluable in managing complexity of programs

Object-oriented programming (OOP)

Everything is an object with a type: `L=[1, 2, 3, 4]` is an **instance** of a `list` object

Abstraction — creating an object type:

- Define internal representation and interface for interacting with object — user only needs interface

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This is **“divide-and-conquer” development**

- Modularity — treat a complex thing like a list as primitive
- Easier to reuse code — keep code clean: eg ‘+’ method for integers and strings

Why define objects?

Suppose you're designing a game where players catch **pocket monsters** and make them fight each other

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# Using lists?
monsters = ['Pikachu','Squirtle','Mew']
combat_strength = [20, 82, 194]
hit_points = [53, 90, 289]
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# Using lists?
monsters = ['Pikachu','Squirtle','Mew']
combat_strength = [20, 82, 194]
hit_points = [53, 90, 289]
```

```
# Using a dictionary?
monsters = {'Pikachu':[20, 53],'Squirtle':[82, 90],'Mew':[194, 289]}
```

Defining an object type

An object contains

- **Data**: attributes (of a monster)
- **Functions**: methods that operate on that data

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Suppose you're designing a game where players catch **pocket monsters** and make them fight each other

```
class Monster(object):
    """
    Attributes and methods
    """
```

`class` statement defines new object type

We’ve created a Monster

Attributes of a monster?

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Attributes of a monster?

```python
class Monster(object):
    """
    Pocket monster
    """
    def __init__(self,combat_strength):
        self.combat_strength = combat_strength

Pikachu = Monster(65)
Squirtle = Monster(278)
print(Pikachu.combat_strength)
```

`self`: Python passes the object itself as the first argument — convention to use word “self”

- But you omit this when calling the function

We’ve created a Monster

Attributes of a monster?

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- Notice the “`.`” operator (like with a `list`)
- The `__init__` method is called when you call `Monster()`

Growing our monsters

```python
class Monster(object):
    def __init__(self, name, combat_strength, hit_points):
        self.name = name
        self.combat_strength = combat_strength
        self.hit_points = hit_points
        self.health = hit_points

    def hurt(self, damage):
        self.health = self.health - damage
        if self.health <= 0:
            print(self.name + ' is dead!')

```

More in the exercises!

Why OOP is useful

Easy to handle many “things” with **common attributes**

Abstraction isolates the use of objects from implementation details

Build **layers of abstractions** — our own on top of Python’s classes

- Keeping track of different monsters and their attributes

Accessing data

```python
class Monster(object):
    def __init__(self, name, combat_strength, hit_points):
        self.name = name
        self.combat_strength = combat_strength
        self.hit_points = hit_points
        self.health = hit_points

    def get_combat_strength(self): # access data through method
        return self.combat_strength

    # more Monster code...

Pikachu = Monster('Pikachu', 100, 30)
cp = Pikachu.combat_strength # a bit risky, could change value accidentally
cp = Pikachu.get_combat_strength() # safer - cannot mess stuff up
```

You **do not have to** write “get” functions like this in Python (in some other languages you do), but may choose to do so.
(If you go deeper into OOP, there are more advanced ways of making data “private”)

Go to menti.com

What is the output?

```
class Monster(object):
    def __init__(self, name):
        self.name = name

pika = Monster('Pikachu')
print(pika.name)
```

A. Pikachu

B. pika

C. self

D. An error

E. I don’t know

What is the output?

```
class Monster(object):
    def __init__(self, name):
        self.name = name

    def print_message(self):
        print('Hello, I am ' + name)

pika = Monster('Pikachu')
pika.name = 'Pika'
pika.print_message()
```

A. Hello, I am Pikachu

B. Nothing

C. An error

D. Hello, I am Pika

E. I don’t know

What is the output?

```python
class Monster(object):
    def __init__(self, name, health):
        self.name = name
        self.health = health

    def hurt(self, damage):
        self.health = self.health - damage

pika = Monster('Pikachu', 100)
pika.hurt(50)
pika.hurt(20)
print(pika.health)
```

A. 100

B. 50

C. 30

D. An error

E. I don't know

What is the output?

```
class Monster(object):
    def __init__(self, name):
        self.name = name

    def greet_other(self, other):
        print(self.name + ' greets ' + other.name)

pika = Monster('Pikachu')
bulb = Monster('Bulbasaur')
pika.greet_other(bulb)
```

A. Pikachu greets Bulbasaur

B. Bulbasaur greets Pikachu

C. Nothing

D. An error

E. I don’t know

Review

Data structures and OOP

- OOP is a way of designing programs to bundle data and actions
- Data structures are ways to organize data efficiently
- Python has excellent data structures for common tasks

Review exercises:

- More Monsters
- A data structure we'll need later: queue

Hacker Challenge

Write a Python program that logs on to the Hub and downloads module files.

I recommend using the `selenium` library.

Details in the Challenge folder on the Hub.

Send me your solution by email before the last lecture. Prize(s) for the best solution(s).

Homework 2

- HW2 Question 4: pick a number, say 1792961, and try $\to k = 1, k = 2, k = 3, \ldots$ to understand what the output should be and develop an algorithm
- HW2 Question 5: think about what we know: each letter appearing first time, second time, ...; start from small.

```
['a', 'c', 'd', 'e', 'b', 'af', 'c', 'd', 'e', 'a', 'c', 'd', 'b', 'af', 'e', 'c', 'd', 'a', 'ce',
'b', 'd', 'af', 'c', 'e', 'a', 'd', 'bc', 'af', 'e', 'd', 'c', 'a', 'd', 'be', 'c', 'af', 'd', 'ce',
'a', 'b', 'd', 'acf', 'e', 'ad', 'c', 'b', 'e', 'af', 'cd', 'ae', 'bc', 'd', 'af', 'ce', 'd', 'a',
'b', 'c', 'de', 'af', 'c', 'd', 'a', 'be', 'c', 'af', 'd']

→ [11, 21, 12, 13, 15, 22]
```

Exam

Mock exam and FAQ on the Hub.

Exam date TBC by programme team.