

# **Data Structures in Python**

## **Chapter 2**

1. Abstract Data Type(ADT)
2. Performance Analysis
3. Big-O Notation
4. Growth Rate
- 5. Growth Rate Examples**

# Agenda & Reading

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- Performance Analysis
  - Introduction
  - Step Counts - Counting Operations
- Big-O Notation - Asymptotic Analysis
  - Properties of Big-O
  - Calculating Big-O
- Growth Rate
  - Comparison
  - Profiling and Prediction
- **Growth Rate Examples**
  - **Python List & Dictionary**
- References:
  - Textbook: Problem Solving with Algorithms and Data Structures
    - Chapter 3. [Analysis](#)
  - Textbook: [www.github.idebtor/DSPy](http://www.github.idebtor/DSPy)
    - Chapter 2.1 ~ 3

# 1 Performance of Python Lists

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- We have a general idea of the performance analysis and big-O notation.
- It is important to **understand the efficiency** of these Python data structures.
  - Now, we will investigate the Big-O performance for the operations on Python **lists** and **dictionaries**.

# 1 Performance of Python Lists - Review

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- Python lists are **ordered sequences** of items.
- Specific values in the sequence can be referenced using subscripts.
- Python lists are:
  - **dynamic**: They can grow and shrink on demand.
  - **heterogeneous**: a single list can hold arbitrary data types.
  - **mutable** sequences of arbitrary objects

# 1 Performance of Python Lists - Operations

- Using operators:

```
my_list = [1,2,3,4]
print(2 in my_list)
```

True

```
zeroes = [0] * 10
print(zeroes)
```

[0,0,0,0,0,0,0,0,0,0]

Operator	Meaning
<seq> + <seq>	Concatenation
<seq> * <int-expr>	Repetition
<seq>[ ]	Indexing
len(<seq>)	Length
<seq>[:]	Slicing
for <var> in <seq>:	Iteration
<expr> in <seq>	Membership (Boolean)

# 1 Performance of Python Lists - Operations

- Using Methods:

Method	Meaning
<code>&lt;list&gt;.append(x)</code>	Add element x to end of list.
<code>&lt;list&gt;.sort()</code>	Sort (order) the list. A comparison function may be passed as a parameter.
<code>&lt;list&gt;.reverse()</code>	Reverse the list.
<code>&lt;list&gt;.Index(x)</code>	Returns Index of first occurrence of x.
<code>&lt;list&gt;.Insert(l, x)</code>	Insert x Into list at Index l.
<code>&lt;list&gt;.count(x)</code>	Returns the number of occurrences of x In list.
<code>&lt;list&gt;.remove(x)</code>	Deletes the first occurrence of x In list.
<code>&lt;list&gt;.pop(l)</code>	Deletes the lth element of the list and returns its value.

# 1 Performance of Python Lists - Examples

```
my_list = [3, 1, 4, 1, 5, 9]  
my_list.append(2)  
my_list.sort()  
my_list.reverse()
```

```
[3, 1, 4, 1, 5, 9, 2]  
[1, 1, 2, 3, 4, 5, 9]  
[9, 5, 4, 3, 2, 1, 1]
```

```
print(my_list.index(4))
```

2

Index of the first occurrence of the parameter

```
my_list.insert(4, "Hello")  
print(my_list)
```

```
[9, 5, 4, 3, 'Hello', 2, 1, 1]
```

```
print(my_list.count(1))
```

2

The number of occurrence of the parameter

```
my_list.remove(1)  
print(my_list)
```

```
[9, 5, 4, 3, 'Hello', 2, 1]
```

```
print(my_list.pop(3))  
print (my_list)
```

3

```
[9, 5, 4, 'Hello', 2, 1]
```

# 1 Performance of Python Lists - Operations

- The **del** statement
  - Removes an item from a list given its index instead of its value.
  - Used to remove slices from a list or clear the entire list.
- Sample Run:

```
my_list = [1, 2, 3, 4]  
ur_list = [4, 3, 2, 1]
```

```
total, max = sum(my_list), max(ur_list)  
print(total, max)
```

10, 4

```
total, max = sum(ur_list), max(ur_list)  
print(total, max)
```

TypeError: 'int' object is not callable



# 1 Performance of Python Lists - Big-O Efficiency of List Operators

<b>index[]</b>	<b><math>O(1)</math></b>
<b>index assignment</b>	<b><math>O(1)</math></b>
<b>append</b>	<b><math>O(1)</math></b>
<b>pop()</b>	<b><math>O(1)</math></b>
<b>pop(i)</b>	<b><math>O(n)</math></b>
<b>insert(i,item)</b>	<b><math>O(n)</math></b>
<b>del operator</b>	<b><math>O(n)</math></b>
<b>iteration</b>	<b><math>O(n)</math></b>
<b>contains (in)</b>	<b><math>O(n)</math></b>
<b>get slice [x:y]</b>	<b><math>O(k)</math></b>
<b>del slice</b>	<b><math>O(n)</math></b>
<b>set slice</b>	<b><math>O(n + k)</math></b>
<b>reverse</b>	<b><math>O(n)</math></b>
<b>concatenate</b>	<b><math>O(k)</math></b>
<b>sort</b>	<b><math>O(n \log n)</math></b>
<b>multiply</b>	<b><math>O(nk)</math></b>

# 1 Performance of Python Lists - $O(1)$ - Constant

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- Operations for **indexing and assigning** to an index position
  - Big-O =  $O(1)$
  - It takes the same amount of time no matter how large the list becomes.
  - i.e., independent of the size of the list

# 1 Performance of Python Lists - Inserting elements to a List

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- There are two ways to create a longer list.
  - Use the **append** method or the **concatenation** operator
- Big-O for the append method is  $O(1)$  .
- Big-O for the concatenation operator is  $O(1)$  where is the size of the list that is being concatenated

# 1 Performance of Python Lists - 4 Experiments

- Four different ways to generate a list of n numbers starting with 0.
  - Use the **append** method or the **concatenation** operator
- Example 1:
  - Using a for loop and create the list by **concatenation**
- Example 2:
  - Using a for loop and the **append** method
- Example 3:
  - Using **list comprehension**
- Example 4:
  - Using the range function wrapped by a call to the **list constructor**.

```
for i in range(n):  
    my_list = my_list + [i]
```

```
for i in range(n):  
    my_list.append(i)
```

```
my_list = [i for i in range(n)]
```

```
my_list = list(range(n))
```

# 1 Performance of Python Lists - 4 Experiments Result

- From the results of our experiment:
  1. Using for loop
    - The **append** operation is much faster than **concatenation**
    - (note) Append: Big-O is  $O(1)$ , Concatenation: Big-O is  $O(k)$
  2. Two additional methods for creating a list
    - Using the **list constructor** with a call to range is much faster than a **list comprehension**
- It is interesting to note that the list comprehension is twice as fast as a for loop with an append operation.

```
for i in range(n):  
    my_list = my_list + [i]
```

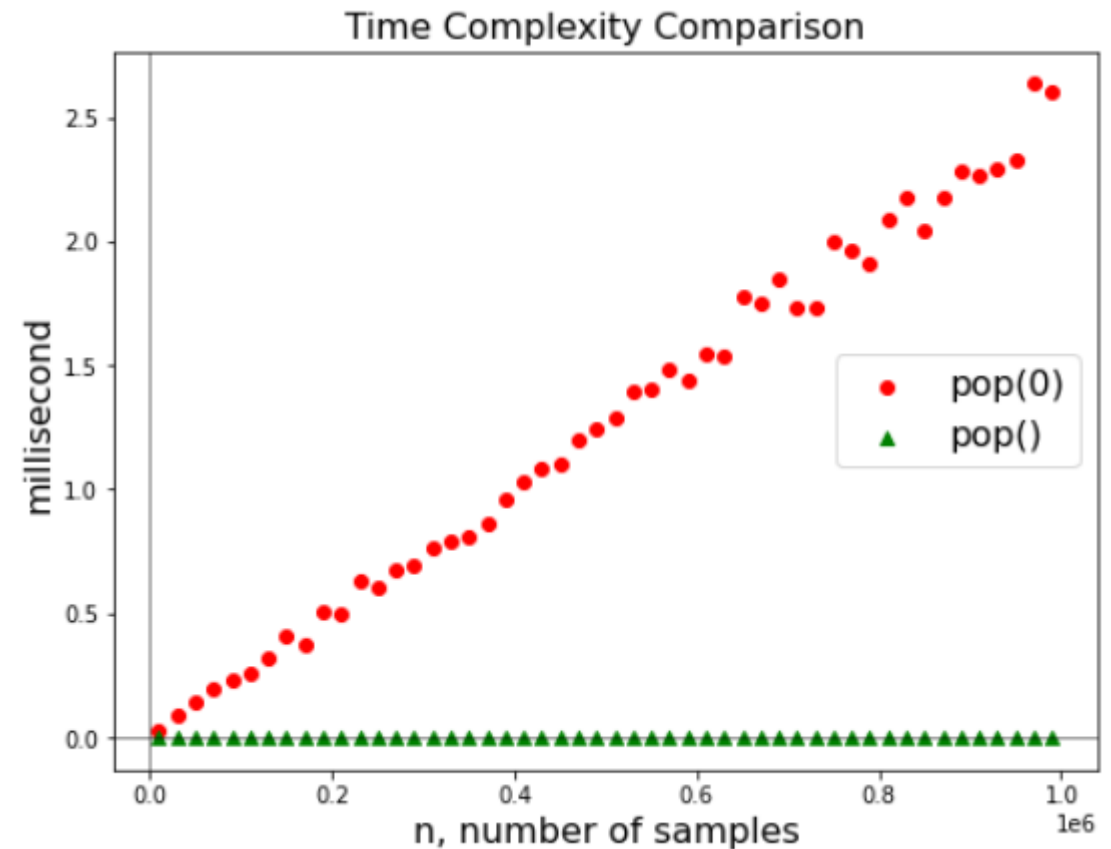
```
my_list = [i for i in range(n)]
```

```
for i in range(n):  
    my_list.append(i)
```

```
my_list = list(range(n))
```

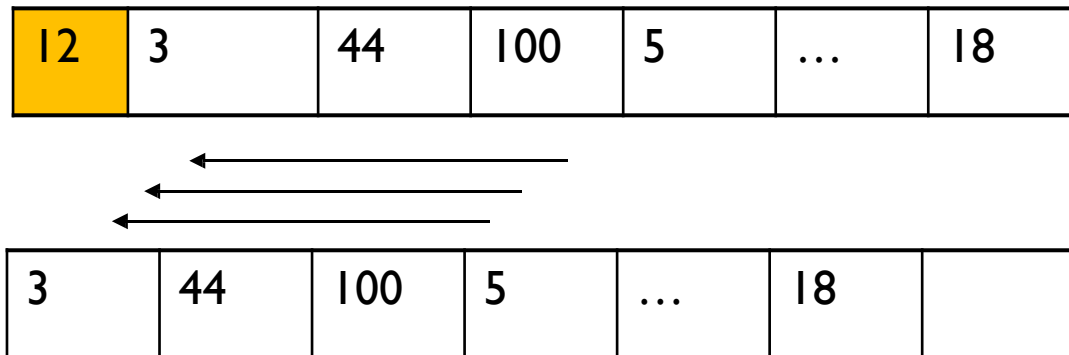
# 1 Performance of Python Lists - Pop() vs Pop(0)

- From the results of our experiment:
  - As the list gets longer and longer the time it takes to pop(0) also increases
  - the time for pop stays very flat.
  - pop(0): Big-O is  $O(n)$
  - pop(): Big-O is  $O(1)$
  - Why?



# 1 Performance of Python Lists - Pop() vs Pop(0)

- `pop()`:
  - Removes element from the end of the list
- `pop(0)`
  - Removes from the beginning of the list.
  - Big-O is  $O(n)$  as we will need to shift all elements from space to the beginning of the list



## 2 Performance of Python Dictionaries

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- Dictionaries store a mapping between a set of **keys** and a set of **values**
  - Keys can be any **immutable** type.
  - Values can be **any** type
  - A single dictionary can store values of different types
- You can define, modify, view, lookup or delete the key-value pairs in the dictionary
- Dictionaries are **unordered**
- Note:
  - Dictionaries differ from lists in that you can access items in a dictionary by a **key** rather than a position.



## 2 Performance of Python Dictionaries - Examples:

```
capitals = {'Korea': 'Seoul', 'Japan': 'Tokyo'}  
print(capitals['Korea'])
```

Seoul

```
capitals['Rwanda'] = 'Kigali'  
print(capitals)
```

{'Korea': 'Seoul', 'Japan': 'Tokyo', 'Rwanda': 'Kigali'}

```
capitals['Taiwan'] = 'Taipei'
```

```
print(len(capitals))  
for k in capitals:  
    print(capitals[k], " is the capital of ", k)
```

4

Seoul is the capital of Korea  
Tokyo is the capital of Japan  
Kigali is the capital of Rwanda  
Taipei is the capital of Taiwan

## 2 Performance of Python Dictionaries - Big-O Efficiency of Operators

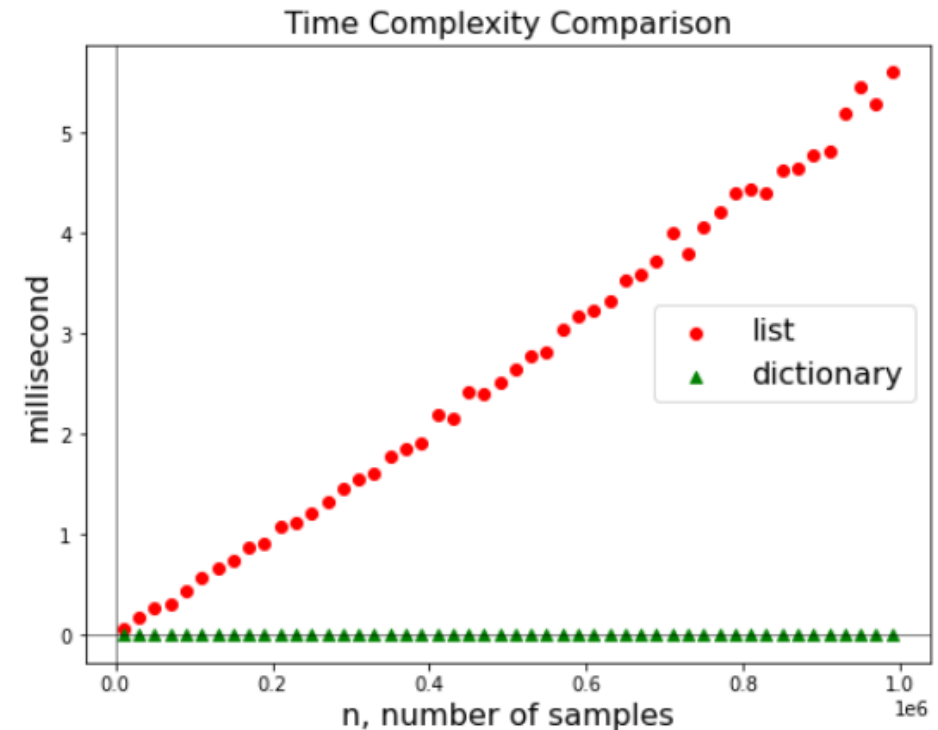
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- Big-O Efficiency of Operators

Operation	Big-O
copy	$O(n)$
get item	$O(1)$
set item	$O(1)$
delete item	$O(1)$
contains (in)	$O(1)$
iteration	$O(n)$

## 2 Performance of Python Dictionaries - Big-O Efficiency of Operators

- **Contains** (**in** operator) between lists and dictionaries
- From the results
  - The time it takes for the contains operator on the list grows linearly with the size of the list.
  - The time for the contains operator on a dictionary is constant even as the dictionary size grows
- Lists, Big-O is  $O(n)$
- Dictionaries, big-O is  $O(1)$



# Summary

- Performance of Python List and Dictionary Operations

index[]	$O(1)$
index assignment	$O(1)$
append	$O(1)$
pop()	$O(1)$
pop(i)	$O(n)$
insert(i,item)	$O(n)$
del operator	$O(n)$
iteration	$O(n)$
contains (in)	$O(n)$
get slice [x:y]	$O(k)$
del slice	$O(n)$
set slice	$O(n + k)$
reverse	$O(n)$
concatenate	$O(k)$
sort	$O(n \log n)$
multiply	$O(nk)$

Operation	Big-O
copy	$O(n)$
get item	$O(1)$
set item	$O(1)$
delete item	$O(1)$
contains (in)	$O(1)$
iteration	$O(n)$