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한동대학교 전산전자공학부

김영섭 교수

교육부 NRF 한국연구재단

Data Structures in Python
Chapter 3 - 2

- Queue
- Deque
- **Deque Profiling**
- Circular Queue

Prof. Youngsup Kim, idebtor@gmail.com, CSEE Dept., Grace School Rm204 Handong Global University

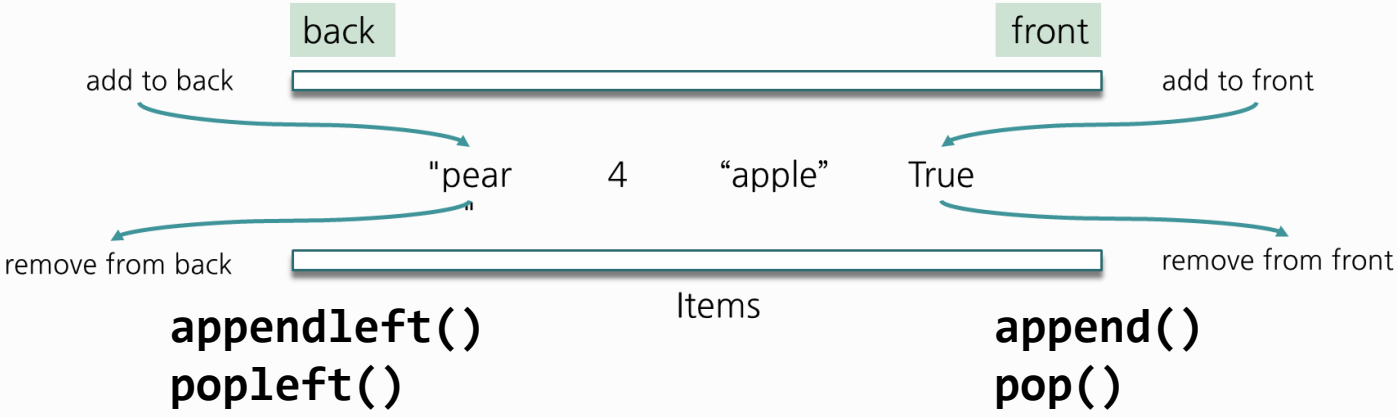
Agenda

- Deque Profiling
  - **`list insert(0, i) vs deque appendleft(i)`**
  - Using `perf_counter()`
  - Lambda Function
  - Profiling

Time Complexity: deque vs list

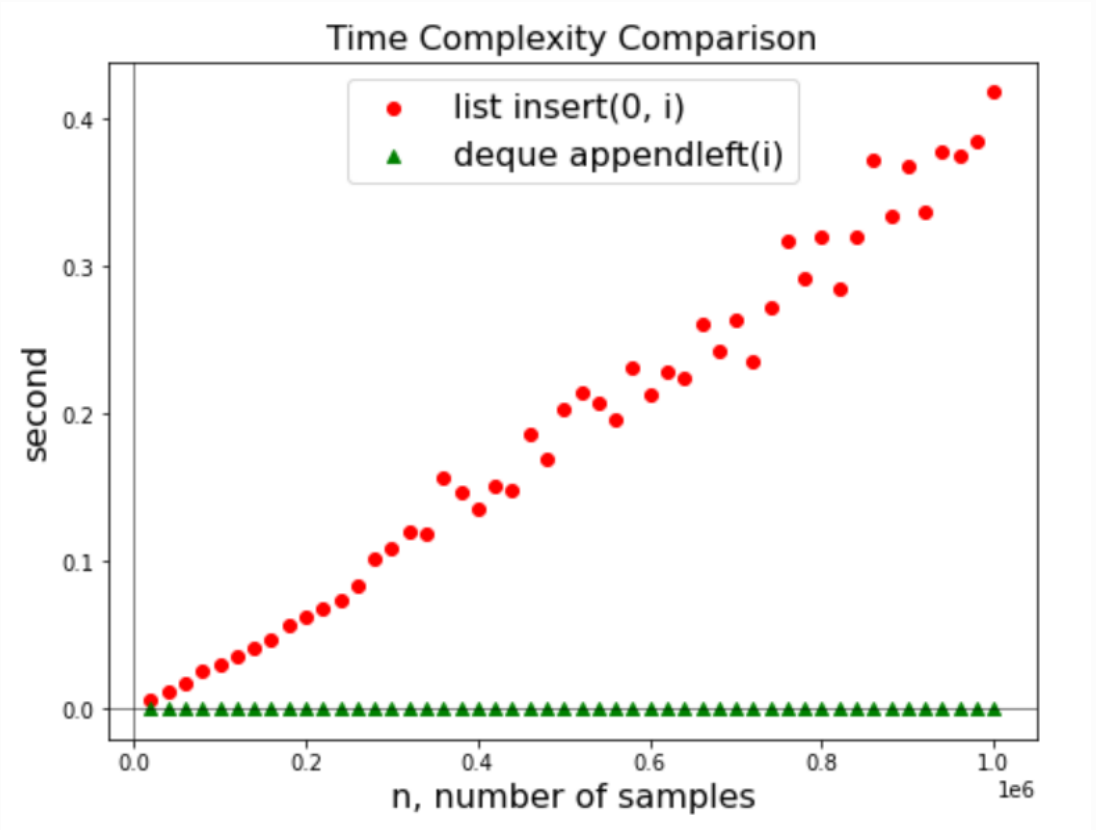
- **Deque** - **Double Ended Queue (pronounced like 'deck')**

Operation	deque	list
Pop and append items on the **left end**	$O(1)$	$O(n)$
Pop and append items on the **right end**	$O(1)$	$O(1)$ + reallocation
Insert and delete items in the **middle**	$O(n)$	$O(n)$
Access **arbitrary items** through indexing	$O(n)$	$O(1)$



Deque Profiling

- Performance Analysis - Time Complexity
  - **`list`의 `insert(0, i)`, `pop(0)` - O(n)**
  - **`deque`의 `appendleft(i)`, `popleft()`, `append()`, `pop()` - O(1)**
- Using **`perf_counter()`** in Python
  - works like a stopwatch.
  - returns the float value of time in seconds.



Deque Profiling: Step 1

- Using built-in performance counter, **perf_counter()**, in Python:

```
#%%writefile perf_counter1.py
from collections import deque
from time import perf_counter  # performance counter

NSIZE = 100_000
TIMES = 100_000
alist = list(range(NSIZE))
t_start = perf_counter()
for i in range(TIMES):
    alist.insert(0, i)
list_time = perf_counter() - t_start
print(f"     list.insert() {list_time:>12.6} sec")

adeq = deque(range(NSIZE))
t_start = perf_counter()
for i in range(TIMES):
    adeq.appendleft(i)
deq_time = perf_counter() - t_start
print(f"deque.appendleft() {deq_time:>12.6} sec")

ratio = list_time / deq_time
print(f"  list/deque ratio {ratio:>12.6} x faster")
```

```
PS C:\GitHub\DSpyx\jupyter> python perf_counter1.py
list.insert()            2.52245 sec
deque.appendleft()    0.0058442 sec
  list/deque ratio       431.616 x faster
PS C:\GitHub\DSpyx\jupyter>
```

Deque Profiling: Step 1

- Using built-in performance counter, **perf_counter()**, in Python:

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#%%writefile perf_counter1.py
from collections import deque
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NSIZE = 100_000
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alist = list(range(NSIZE))
t_start = perf_counter()
for i in range(TIMES):
    alist.insert(0, i)
list_time = perf_counter() - t_start
print(f"list.insert()      {list_time:>12.6} sec")
```

```
adeq = deque(range(NSIZE))
t_start = perf_counter()
for i in range(TIMES):
    adeq.appendleft(i)
deq_time = perf_counter() - t_start
print(f"deque.appendleft() {deq_time:>12.6} sec")

ratio = list_time / deq_time
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alist = list(range(NSIZE))
t_start = perf_counter()
for i in range(TIMES):
    alist.insert(0, i)
list_time = perf_counter() - t_start
print(f"list.insert()      {list_time:>12.6} sec")
```

```
adeq = deque(range(NSIZE))
t_start = perf_counter()
for i in range(TIMES):
    adeq.appendleft(i)
deq_time = perf_counter() - t_start
print(f"deque.appendleft() {deq_time:>12.6} sec")

ratio = list_time / deq_time
print(f"  list/deque ratio {ratio:>12.6} x faster")
```

These two code snippets are almost identical.
It violates one of coding principles:

```
PS C:\GitHub\DSpyx\jupyter> python perf_counter1.py
list.insert()            2.52245 sec
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PS C:\GitHub\DSpyx\jupyter>
```

Deque Profiling: Step 2

- Let us make them as functions like `list_timing()` and `deq_timing()`.

```
#%%writefile perf_counter1.py
from collections import deque
from time import perf_counter  # performance counter

NSIZE = 100_000
TIMES = 100_000
alist = list(range(NSIZE))
t_start = perf_counter()
for i in range(TIMES):
    alist.insert(0, i)
list_time = perf_counter() - t_start
print(f"list.insert()      {list_time:>12.6} sec")
```

Let us rewrite each part as a function, **`list_timing()`**, that returns **`list_time`** and **`deq_timing()`** that returns **`deq_time`**.

`#%%writefile perf_counter2.py`

```
def list_timing(NSIZE, TIMES):
    alist = list(range(NSIZE))
    start = perf_counter()
    for i in range(TIMES):
        alist.insert(0, i)
    return perf_counter() - start

def deq_timing(NSIZE, TIMES):
    adeq = deque(range(NSIZE))
    start = perf_counter()
    for i in range(TIMES):
        adeq.appendleft(i),
    return perf_counter() - start
```

Deque Profiling: Step 2

- Let us make them as functions like `list_timing()` and `deq_timing()`.

```
#%%writefile perf_counter2.py
from collections import deque
from time import perf_counter  # performance counter

def list_timing(NSIZE, TIMES):
    alist = list(range(NSIZE))
    start = perf_counter()
    for i in range(TIMES):
        alist.insert(0, i)
    return perf_counter() - start

def deq_timing(NSIZE, TIMES):
    adeq = deque(range(NSIZE))
    start = perf_counter()
    for i in range(TIMES):
        adeq.appendleft(i)
    return perf_counter() - start
```

```
if __name__ == '__main__':
    NSIZE = 100_000
    TIMES = 100_000
    list_time = list_timing(NSIZE, TIMES)
    print(f"    list.insert() {list_time:>12.6} sec")
    deq_time = deq_timing(NSIZE, TIMES)
    print(f"deque.appendleft(){deq_time:>12.6} sec")
    ratio = list_time / deq_time
    print(f" list/deque ratio{ratio:>12.6} xfaster")
```

```
PS C:\GitHub\DSpyx\jupyter> python perf_counter2.py
list.insert()            2.49762 sec
deque.appendleft()    0.0051234 sec
  list/deque ratio      487.492 x faster
PS C:\GitHub\DSpyx\jupyter>
```

Deque Profiling: Step 2

- Let us make them as functions like `list_timing()` and `deq_timing()`.

```
#%%writefile perf_counter2.py
from collections import deque
from time import perf_counter  # performance counter

def list_timing(NSIZE, TIMES):
    alist = list(range(NSIZE))
    start = perf_counter()
    for i in range(TIMES):
        alist.insert(0, i)
    return perf_counter() - start

def deq_timing(NSIZE, TIMES):
    adeq = deque(range(NSIZE))
    start = perf_counter()
    for i in range(TIMES):
        adeq.appendleft(i)
    return perf_counter() - start
```

These two functions are almost identical.
It still violates one of coding principles:

Deque Profiling: Step 3

- Combine two **~_timing()**functions to **perf_timeit().** Make a helper function **elapsed()** that accepts **list insert()** and **deque appendleft()** as an argument.

```
#%%writefile perf_counter2.py
from collections import deque
from time import perf_counter

def list_timing(NSIZE, TIMES):
    alist = list(range(NSIZE))
    start = perf_counter()
    for i in range(TIMES):
        alist.insert(0, i)
    return perf_counter() - start

def deq_timing(NSIZE, TIMES):
    adeq = deque(range(NSIZE))
    start = perf_counter()
    for i in range(TIMES):
        adeq.appendleft(i)
    return perf_counter() - start
```

```
#%%writefile perf_counter3.py
from collections import deque
from time import perf_counter

def perf_timeit(NSIZE, TIMES):
    alist = list(range(NSIZE))
    adeq = deque(range(NSIZE))

    def elapsed(func)          # a helper function
        start = perf_counter()
        for i in range(TIMES):
            func(i)
        return perf_counter() - start

    list_time = elapsed(... alist.insert(0, i))
    deq_time  = elapsed(... adeq.appendleft(i))
    return list_time, deq_time
```

Pass this as an argument to the function **elapsed().**

Deque Profiling: Step 4

- Let us learn about lambda function or define an anonymous function in one line.
- Syntax: **`lambda argument(s): expression`**
- Example:

```
def times2plus(x, y):                # regular function
    return x * 2 + y
lambda x, y: x * 2 + y               # lambda function
```

```
(lambda x, y: x * 2 + y)(1, 2)  # returns 4
```

```
func = lambda x, y: x * 2 + y
func(3,4)                            # returns 10
```

```
>>> (lambda x, y: x * 2 + y)(1, 2)
4
>>> func = lambda x, y: x * 2 + y
>>> func(3,4)
10
>>>
```

Deque Profiling: Step 4

- Let us learn about lambda function or define an anonymous function in one line.
- Syntax: **`lambda argument(s): expression`**
- Example:

```
def times2plus(x, y):                # regular function
    return x * 2 + y
lambda x, y: x * 2 + y               # lambda function
```

```
(lambda x, y: x * 2 + y)(1, 2)  # returns 4
```

```
func = lambda x, y: x * 2 + y
func(3,4)                            # returns 10
```

```
>>> (lambda x, y: x * 2 + y)(1, 2)
4
>>> func = lambda x, y: x * 2 + y
>>> func(3,4)
10
>>>
```

- Example:

```
>>> list(map(lambda x: x.capitalize(), ['cat', 'dog', 'cow']))
['Cat', 'Dog', 'Cow']
```

```
>>> [x.capitalize() for x in ['cat', 'dog', 'cow']]
```

Deque Profiling: Step 4

- Let us learn about lambda function or define an anonymous function in one line.
- Syntax: **`lambda argument(s): expression`**
- Example:

```
def times2plus(x, y):                # regular function
    return x * 2 + y
lambda x, y: x * 2 + y               # lambda function
```

```
(lambda x, y: x * 2 + y)(1, 2)  # returns 4
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```
func = lambda x, y: x * 2 + y
func(3,4)                            # returns 10
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```
>>> (lambda x, y: x * 2 + y)(1, 2)
4
>>> func = lambda x, y: x * 2 + y
>>> func(3,4)
10
>>>
```

- Example:

```
>>> list(map(lambda x: x.capitalize(), ['cat', 'dog', 'cow']))
['Cat', 'Dog', 'Cow']
```

```
>>> [x.capitalize() for x in ['cat', 'dog', 'cow']]
```

- Example:

```
>>> from timeit import timeit
>>> from math import factorial
>>> timeit("factorial(999)", "from math import factorial", number=10)
0.0013087529951008037
```

setup

```
>>> timeit(lambda: factorial(999), number=10)
```

Deque Profiling: Step 5

A performance test code using **perf_counter()** and lambda function:

```
#%%writefile perf_counter3.py
from collections import deque
from time import perf_counter  # performance counter

def perf_timeit(NSIZE, TIMES):
    alist = list(range(NSIZE))
    adeq = deque(range(NSIZE))

    def elapsed(func):          # a helper function
        start = perf_counter()
        for i in range(TIMES):
            func(i)
        return perf_counter() - start

    list_time = elapsed(None)  # your code here
    deq_time  = elapsed(None)
    return list_time, deq_time
```

```
if __name__ == '__main__':
    NSIZE = 100_000
    TIMES = 100_000
    list_time, deq_time = perf_timeit(NSIZE, TIMES)
    print(f"     list.insert() {list_time:>12.6} sec")
    print(f"deque.appendleft() {deq_time:>12.6} sec")
    ratio = list_time / deq_time
    print(f"  list/deque ratio {ratio:>12.6} x faster")
```

Deque Profiling: Step 5

A performance test code using **perf_counter()** and lambda function:

```
#%%writefile perf_counter3.py
from collections import deque
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def perf_timeit(NSIZE, TIMES):
    alist = list(range(NSIZE))
    adeq = deque(range(NSIZE))

    def elapsed(func):          # a helper function
        start = perf_counter()
        for i in range(TIMES):
            func(i)
        return perf_counter() - start

    list_time = elapsed(None)  # your code here
    deq_time  = elapsed(None)
    return list_time, deq_time
```

```
if __name__ == '__main__':
    NSIZE = 100_000
    TIMES = 100_000
    list_time, deq_time = perf_timeit(NSIZE, TIMES)
    print(f"     list.insert() {list_time:>12.6} sec")
    print(f"deque.appendleft() {deq_time:>12.6} sec")
    ratio = list_time / deq_time
    print(f"  list/deque ratio {ratio:>12.6} x faster")
```

```
PS C:\GitHub\DSpyx\jupyter> python perf_counter3.py
     list.insert()      2.51812 sec
deque.appendleft()    0.0065251 sec
  list/deque ratio      385.913 x faster
PS C:\GitHub\DSpyx\jupyter>
```

Deque Profiling: Step 6 - Exercise

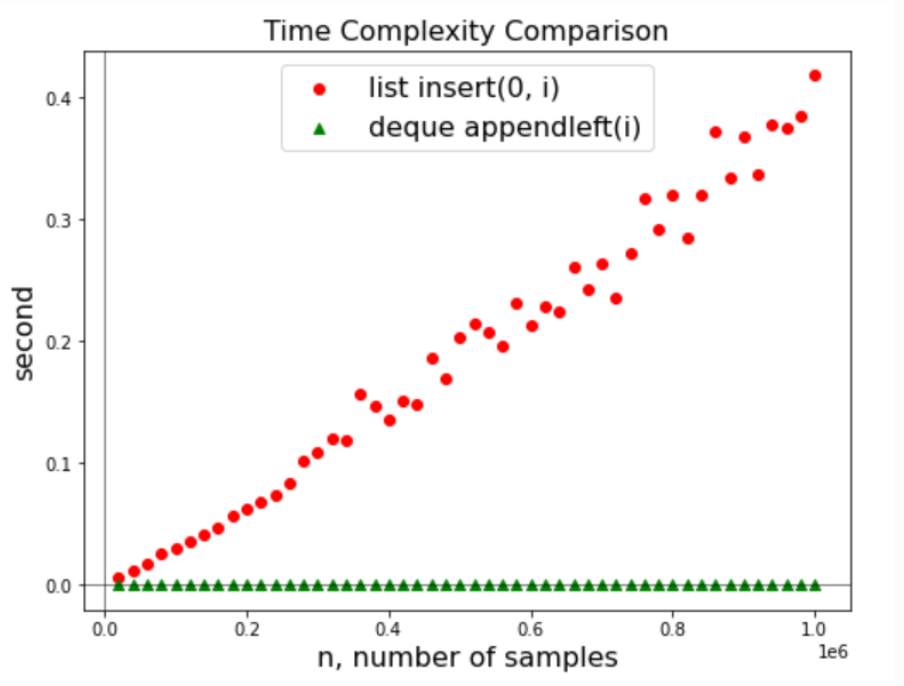
Use `perf_timeit()` instead of `timeit.timeit()` for the performance analysis.

```
#%%writefile perf_counter3.py
from collections import deque
from time import perf_counter  # performance counter

def perf_timeit(NSIZE, TIMES):
    alist = list(range(NSIZE))
    adeq = deque(range(NSIZE))

    def elapsed(func):          # a helper function
        start = perf_counter()
        for i in range(TIMES):
            func(i)
        return perf_counter() - start

    list_time = elapsed(None)  # your code here
    deq_time  = elapsed(None)
    return list_time, deq_time
```



Deque Profiling: Step 6 - Exercise

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```
#%%writefile perf_counter3.py
from collections import deque
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def perf_timeit(NSIZE, TIMES):
    alist = list(range(NSIZE))
    adeq = deque(range(NSIZE))

    def elapsed(func):          # a helper function
        start = perf_counter()
        for i in range(TIMES):
            func(i)
        return perf_counter() - start

    list_time = elapsed(None)  # your code here
    deq_time  = elapsed(None)
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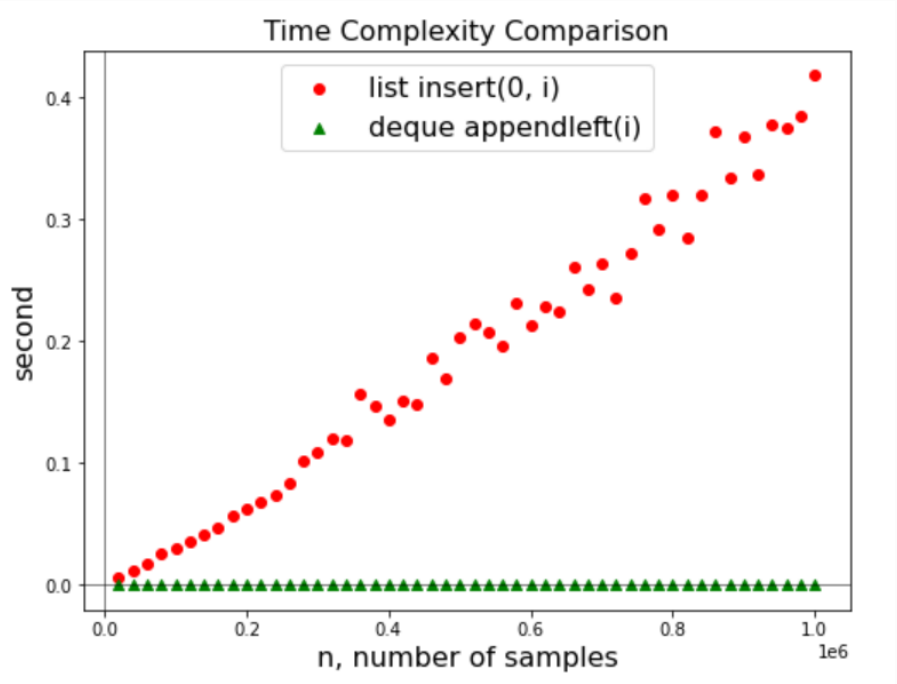
```




```
if __name__ == '__main__':
    list_time = []    # list of list_time values
    deque_time = []   # list of deque_time values
    n = []            # list of samples for plotting

    for i in range(20_000, 1_000_001, 20_000):
        None          # your code here
```

Summary

- The **deque** in Python was designed to guarantee efficient **append and pop** operations on either end of the sequence in O(1).
  - `perf_counter()` - Performance counter in Python
  - Lambda Function - Anonymous Function or Lambda Expression
- Now, you may decide when to use `deque` instead of `list`.

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