# Lab 5: Linked Lists Solution

## 4) Additional exercises

### Generalizing *__getitem__*

The implementation we've provided for *__getitem__* has many shortcomings compared to Python's built-in lists.

Two features that it doesn't currently support are negative indexes and slices (e.g., *my_list[2:5]*).

Your first task here is to investigate the different ways in which Python supports these operations for built-in Python lists; you can do this by experimenting yourself in the Python console, or by doing some reading online.

Then, modify the linked list implementation of *__getitem__* so that it handles both negative indexes and slices.

Note that a slice in Python is actually a class: the expression *my_list[2:5]* is equivalent to *my_list.__getitem__(slice(2, 5))*.

Use *isinstance* to determine whether the input to *__getitem__* is an integer or a slice.

The fully general method signature of *__getitem__* should become:

```
    def __getitem__(self, index: Union[int, slice]) -> Union[Any,
LinkedList]
```

Note: slicing should always return a new *LinkedList* object.

This means that for a given slice, you'll need to create a *LinkedList* and new *_Nodes* as well, in a similar manner to how you implemented the more powerful initializer at the end of Task 1.

**Negative Index:**

```
    class LinkedList:
    ...
        def __getitem__(self, index: int) -> Any:
            """Return the item at position <index> in this list.

            Raise IndexError if <index> is >= the length of this list.
```

```
            >>> lst = LinkedList([1, 2, 10, 200])
            >>> lst[-1]
            200
            >>> lst[2]
            10
            >>> lst[-10]
            Traceback (most recent call last):
                ...
            IndexError
            >>> str(lst[:2])
            '[1 -> 2]'
            >>> str(lst[10:1:-1])
            '[200 -> 10]'
            """
            curr = self._first
            curr_index = 0
            # ============= (Task 4, Part 1) =============
            index = index if index >= 0 else self._length + index

            if index < 0:
                raise IndexError
            # ============================================

            while curr is not None and curr_index < index:
                curr = curr.next
                curr_index += 1

            assert curr is None or curr_index == index

            if curr is None:
                raise IndexError
            else:
                return curr.item
```

Listing 1: task_4_part_1_solution.py

**Slices:**

```
    class LinkedList:
    ...
        # ============= (Task 4, Part 1) =============
        def __getitem__(self, index: Union[int , slice]) -> Union[Any ,
    LinkedList]:
            """Return the item at position <index> in this list.

            Raise IndexError if <index> is >= the length of this list.

            >>> lst = LinkedList([1, 2, 10, 200])
            >>> lst[-1]
            200
            >>> lst[2]
```

```
            10
            >>> lst[-10]
            Traceback (most recent call last):
                ...
            IndexError
            >>> str(lst[:2])
            '[1 -> 2]'
            >>> str(lst[10:1:-1])
            '[200 -> 10]'
            """

            if isinstance(index, slice):
                curr = self._first
                curr_index = 0
                start, stop, step = index.indices(len(self))
                # 1. initialize list
                i_list = range(start, stop, step)
                result = []

                for i in i_list:
                    # 2. fetch value from linked list
                    try:
                        item = self[i]

                        # 3. if it exists, insert to result
                        result.append(item)
                    except IndexError:
                        # 4. if it doesn't exist, then continue
                        continue

                return LinkedList(result)

            else:
                curr = self._first
                curr_index = 0
                index = index if index >= 0 else self._length + index

                if index < 0:
                    raise IndexError

                while curr is not None and curr_index < index:
                    curr = curr.next
                    curr_index += 1

                assert curr is None or curr_index == index

                if curr is None:
                    raise IndexError
                else:
                    return curr.item
        # ============================================
```

Listing 2: task_4_part_1_solution.py

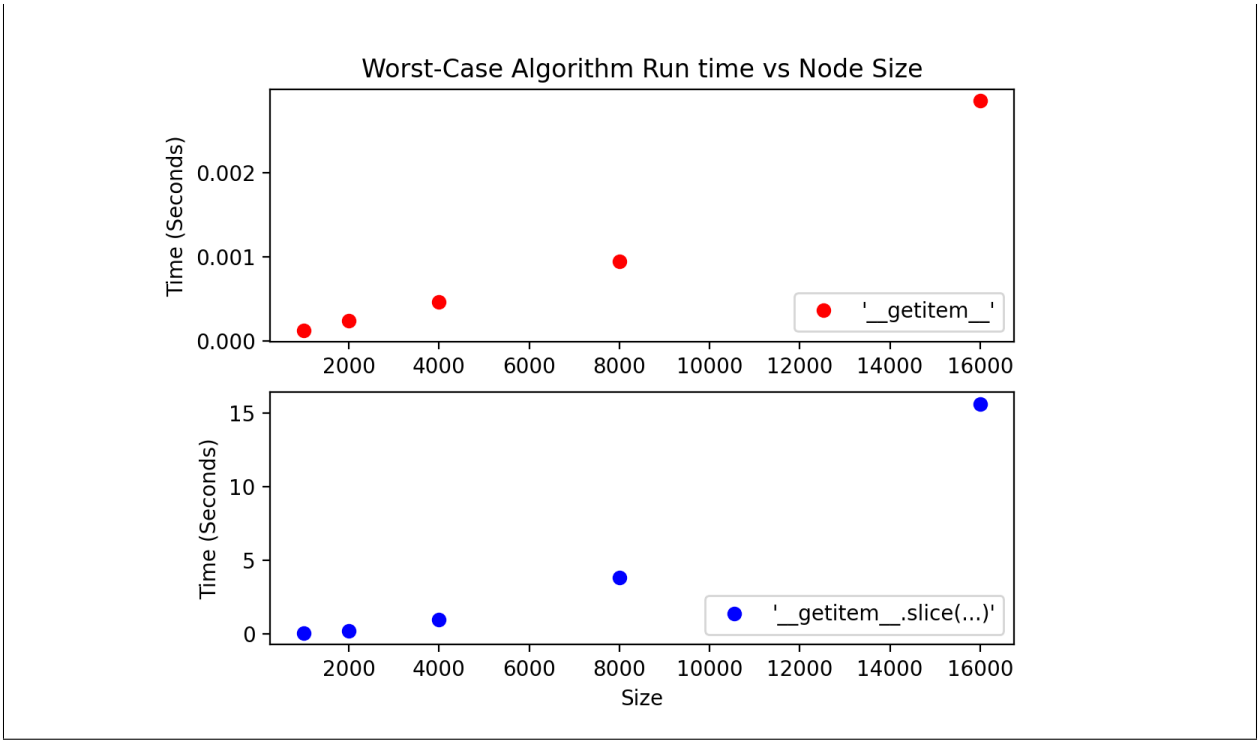
## Matplotlib Practice

Use *matplotlib* to plot the results of your timing experiments, using the same approach as last week (See matplotlib section in lab 4).

```
    """CSC148 Lab 5: Linked Lists

    === CSC148 Winter 2020 ===
    Department of Computer Science,
    University of Toronto

    === Module description ===
    This module runs timing experiments to determine how the time taken
    to call ‘len‘ on a Python list vs. a LinkedList grows as the list
    size grows.
    """
    from timeit import timeit
    from task_4_part_1_solution import LinkedList
    import matplotlib.pyplot as plt

    NUM_TRIALS = 3000                       # The number of trials to
    run.
    SIZES = [1000, 2000, 4000, 8000, 16000]  # The list sizes to try.

    def profile_getitem(list_class: type, size: int) -> float:
        """Return the time taken to call len on a list of the given
    class and size.

        Precondition: list_class is either list or LinkedList.
        """
        # TODO: Create an instance of list_class containing <size> 0's.
        my_list = LinkedList([0 for x in range(size)])

        # TODO: call timeit appropriately to check the runtime of len
    on the list.
        # Look at the Lab 4 starter code if you don't remember how to
    use timeit:
        # https://www.teach.cs.toronto.edu/~csc148h/winter/labs/w4_ADTs
    /starter-code/timequeue.py

        time = timeit('my_list[-1]', number=1, globals=locals())

        return time

    def profile_slice(list_class: type, size: int) -> float:
        """Return the time taken to call len on a list of the given
    class and size.

        Precondition: list_class is either list or LinkedList.
        """
        # TODO: Create an instance of list_class containing <size> 0's.
        my_list = LinkedList([0 for x in range(size)])
```

```
        n = len(my_list)

        # TODO: call timeit appropriately to check the runtime of len
    on the list.
        # Look at the Lab 4 starter code if you don't remember how to
    use timeit:
        # https://www.teach.cs.toronto.edu/~csc148h/winter/labs/w4_ADTs
    /starter-code/timequeue.py

        time = timeit('my_list[n::-1]', number=1, globals=locals())

        return time



    if __name__ == '__main__':
        getitem_time_list = []
        slice_time_list = []

        for list_class in [LinkedList]:
            # Try each list size
            print('========== __getitem__ ==========')
            for s in SIZES:
                time = profile_getitem(list_class, s)
                getitem_time_list.append(time)
                print(f'[{list_class.__name__}] Size {s:>6}: {time}')

            print('========== slice ==========')

            for s in SIZES:
                time = profile_slice(list_class, s)
                slice_time_list.append(time)
                print(f'[{list_class.__name__}] Size {s:>6}: {time}')

        ax = plt.subplot(1,1,1)

        ax1 = plt.subplot(2, 1, 1)
        plt1, = ax1.plot(SIZES, getitem_time_list, 'ro')
        ax1.legend([plt1],["'__getitem__'"], loc="lower right")
        ax1.set_ylabel ('Time (Seconds)')
        ax1.set_title('Worst-Case Algorithm Run time vs Node Size')

        ax2 = plt.subplot(2, 1, 2)
        plt2, = ax2.plot(SIZES, slice_time_list, 'bo')
        ax2.legend([plt2],["'__getitem__.slice(...)'"], loc="lower
    right")
        ax2.set_xlabel('Size')
        ax2.set_ylabel('Time (Seconds)')

        plt.show()

```

Listing 3: task_4_part_2_solution.py


Worst-Case Algorithm Run time vs Node Size
Time (Seconds)
0.000
0.001
0.002
2000
4000
6000
8000
10000
12000
14000
16000
'__getitem__'
Time (Seconds)
0
5
10
15
'__getitem__.slice(...)'
Size