What is a Linked List

A linked list is a structure used for storing a collection of data that has the following properties:

- Successive elements are connected with a pointer (*not necessarily contiguous memory*)
- The last element points to `nothing`
- They grow and shrink during the execution of the program (*mutable*)
- Can be made as long as required (memory bound)

Abstract Data Type

Main Operations

- **Insert**: insert an element to the list
- **Delete**: delete an element from the list

Auxiliary Operations

- *Delete List*: delete the list and all its elements
- *Count*: give the length of the list
- *Find nth node from the end of the list*

Difference with Array (SArray in Julia)

Array elements are **contoguous in memory** and can be accessed in constant time (given the pointer at the beginning and the length of each element, you just need to read `n*size(typeof(element))` and move the pointer)

Advantages

- Read and Write element in O(1)
- Easy to use
- Deletion and insertion at ending is easy (if the array is not full)

Disadvantages

- **Fixed size**: once the memory is allocated that's the size of the array
- **Block allocation**: need to find the space
- **Waste of space**: if you only use part of the array
- **Complex position based insetion**: If the array is smaller than its maximum size and I wand to insert or remove an element at a certain position, I need to move ALL the other elements coming after (expensive at worst O(N) if it's at the beginning)

Difference with Dynamic Arrays (is it the impremelentation of Array in Julia? Not sure)

Also knows as **array lists**, they are similar to static arrays, but when one finishes, I can allocate a new chunck of memory and linking it.

Something in between lists and arrays

Linked Lists

Advantages

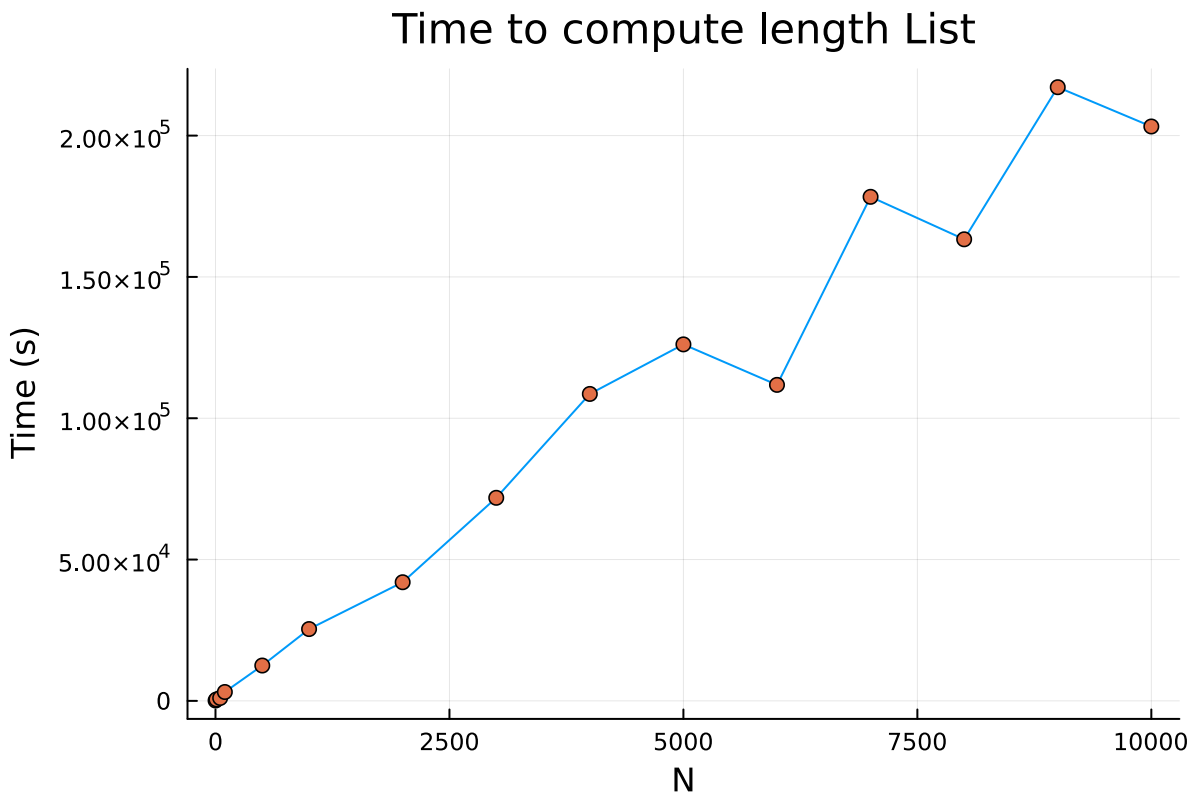
- Can insert an element in O(1):
    - Create a new element at new_ptr
    - Get tmp -> old_ptr
    - Change olt_ptr-> new_ptr
    - Point my new object to new_ptr
- I can easily make a linked list of different elements

Disagvantages

- Reaching any point except the beginning can take O(N) (thus for insertion I need to take that into account)

Single Linked List

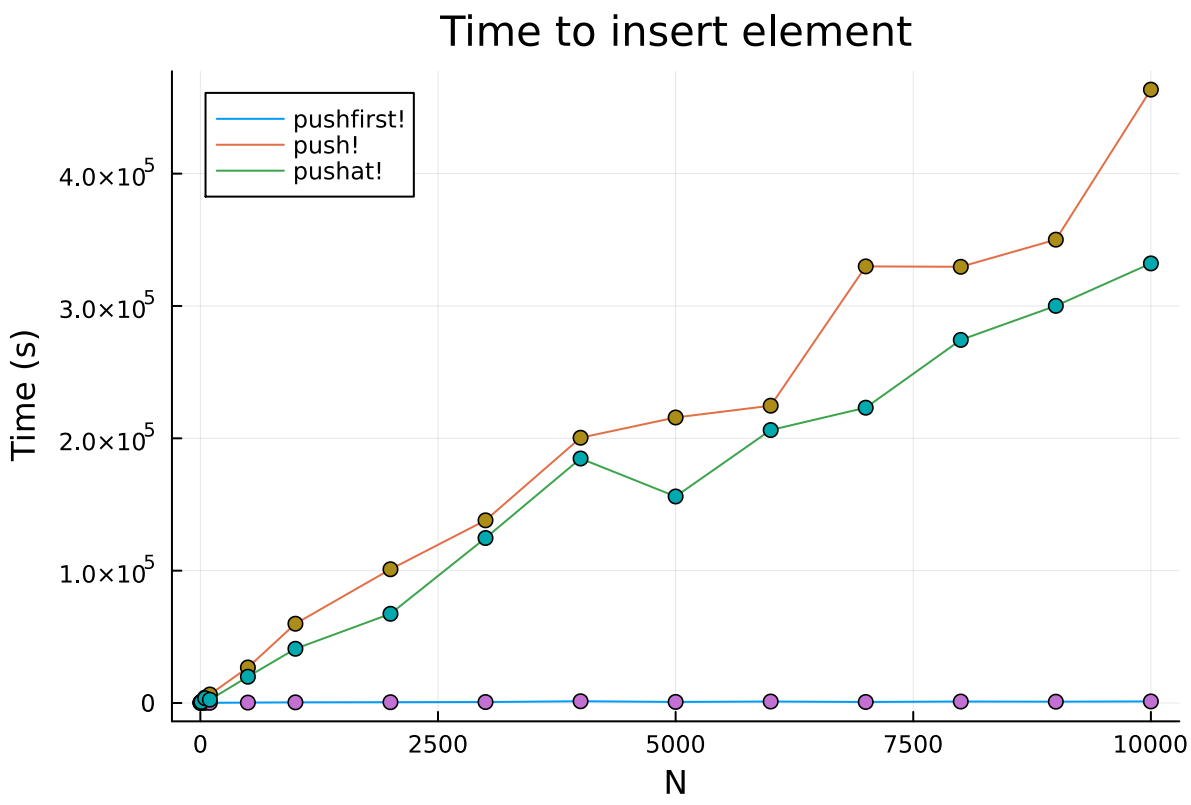
Traverse:



To traverse it I neeto to get all the elements in the list until I hit `Nothing` (see `ListLength`)

- Time Complexity: O(N) [to traverse while counting]
- Space Complexity: O(1) [to allocate counter]

Insert Node:



Insert at the beginning (`pushfirst!`)

- Create new element `new_node`

- Make new_node point at `head`
- Substitute pointed to `head` to pointer to `new_node`

- Time Complexity: O(1)
- Space Complexity: O(1)

Insert at the end (`push!`)

- Create new element `new_node`
- Travel to the end (O(N))
- Modify last pointed to `nothing` -> `new_node`

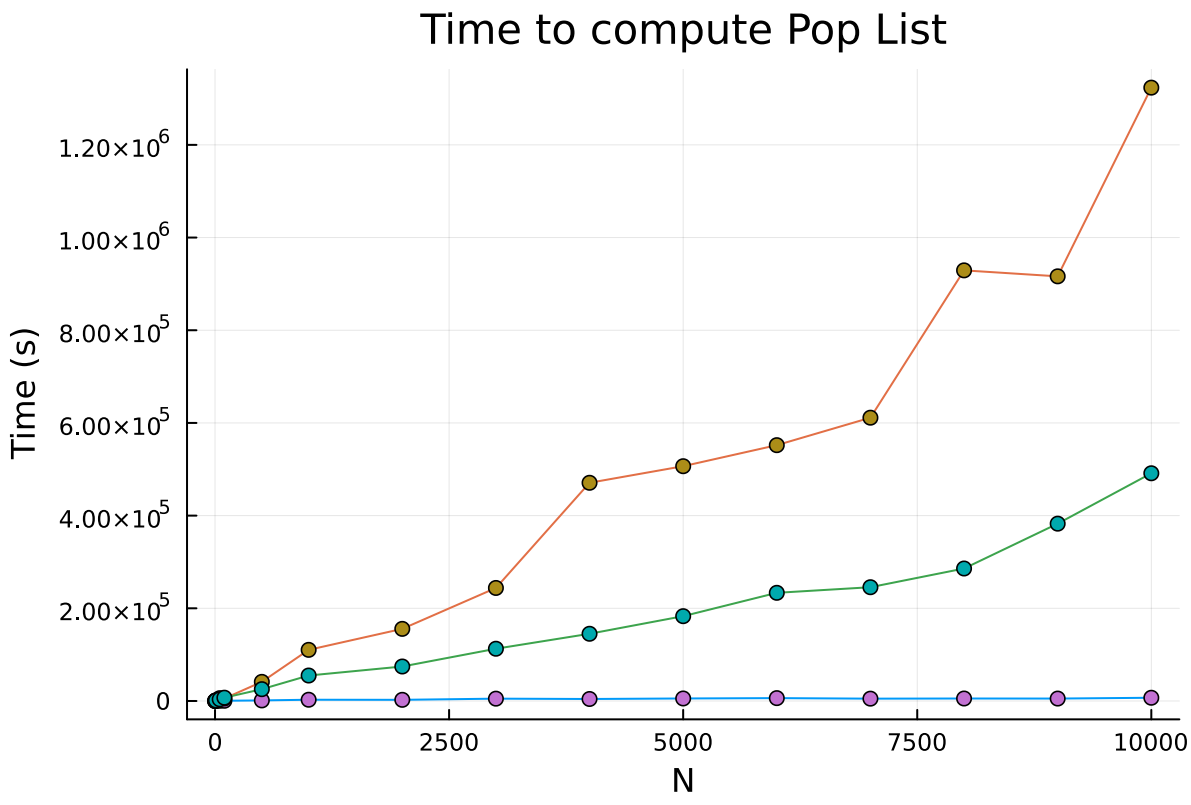
- Time Complexity: O(N)
- Space Complexity: O(1)

Insert in the middle (`pushat!`)

- Create new element `new_node`
- Travel to `n-1` nodes
- copy pointer of `n-1` in `tmp`
- change pointer of `n-1`->`new_pointer`
- Point new pointer to tmp

- Time Complexity: O(N)
- Space Complexity: O(1)

Delete Node



Delete at the beginning (`popfirst!`)

- new_head= next(head)
- list.head=new_head
- no need to get rid of the node: **garbage collection**

- Time Complexity: O(1)
- Space Complexity: O(1)

Delete at the end (`pop!`)

- Create new element `new_node`
- Travel to the end-1 O(N)
- Set `end-1` node.next to `nothing
- garbage collection

- Time Complexity: O(N)
- Space Complexity: O(1)

Delete in the middle

- Create new element `new_node`
- Travel to `i-1` node (up to O(N))
- set new_node.next-> i-1 node.next
- set i-2 node.next -> new_node

- Time Complexity: O(N)
- Space Complexity: O(1)