Slido Event #24766140
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Lecture 2: List Case Study

CSE 373: Data Structures and Algorithms

Agenda

Quick ADT Review

List Case Study

Generics

Questions

Announcements

Things are live!

- course website – one stop for all things 373
- Ed board – get your course content questions answered + connect with students
- Gradescope

Project 0 Released – Due Wednesday 4/5

- 143 review
- Head TA Maia is offering setup OH Friday 12:30-2:00pm CSE2 345
- Get started on setup now!

Office Hours officially start next week

Section starts tomorrow

Quick ADT Review

List Case Study

Generics

Questions

Review: Full Definitions

- Abstract Data Type (ADT)
  - *A definition for expected operations and behavior*
  - A mathematical description of a collection with a set of supported operations and how they should behave when called upon
  - Describes what a collection does, not how it does it
  - Can be expressed as an interface
  - Examples: List, Map, Set
- Data Structure
  - *A way of organizing and storing related data points*
  - An object that implements the functionality of a specified ADT
  - Describes exactly how the collection will perform the required operations
  - Examples: LinkedIntList, ArrayIntList

ADTs we'll discuss this quarter

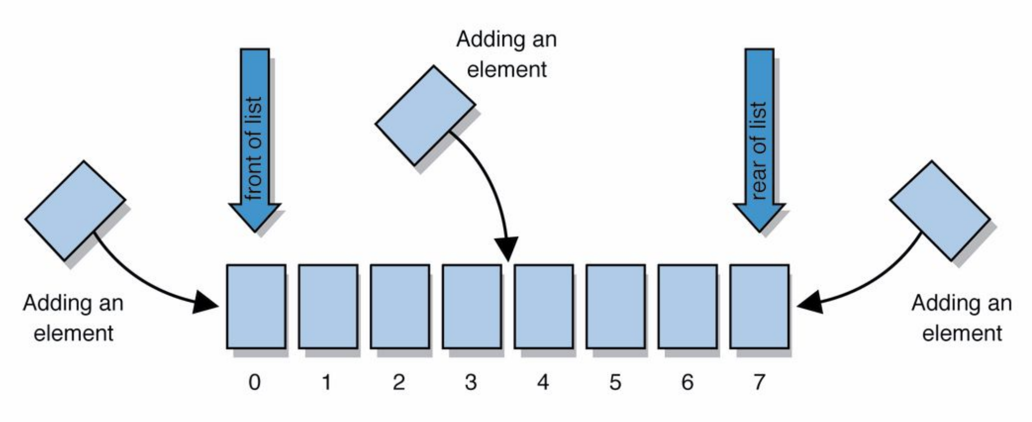
- List: an ordered sequence of elements
- Set: an unordered collection of elements
- Map: a collection of "keys" and associated "values"
- Stack: a sequence of elements that can only go in or out from one end
- Queue: a sequence of elements that go in one end and exit the other
- Priority Queue: a sequence of elements that is ordered by "priority"
- Graph: a collection of points/vertices and edges between points
- Disjoint Set: a collection of sets of elements with no overlap

Questions?

Case Study: The List ADT

list: a collection storing an ordered sequence of elements

- Each item is accessible by an index
- A list has a size defined as the number of elements in the list



Expected Behavior:

- `get(index)`: returns the item at the given index
- `set(value, index)`: sets the item at the given index to the given value
- `append(value)`: adds the given item to the end of the list
- `insert(value, index)`: insert the given item at the given index maintaining order
- `delete(index)`: removes the item at the given index maintaining order
- `size()`: returns the number of elements in the list

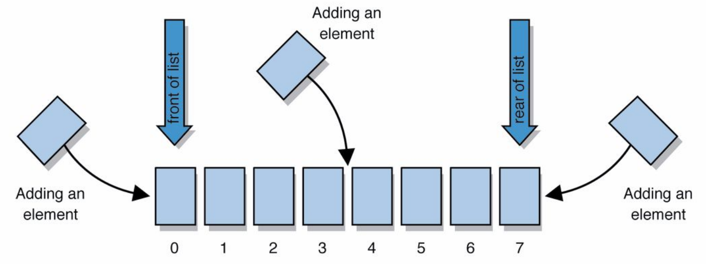
```
List<String> names = new ArrayList<>();
names.add("Anish");
names.add("Amanda");
names.add(0, "Brian");
```

Case Study: List Implementations

List ADT

state
Set of ordered items
Count of items

behavior
get(index) return item at index
set(item, index) replace item at index
append(item) add item to end of list
insert(item, index) add item at index
delete(index) delete item at index
size() count of items

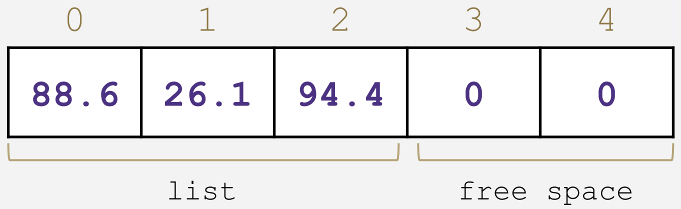


ArrayList
uses an Array as underlying storage

ArrayList<E>

state
data[]
size

behavior
get return data[index]
set data[index] = value
append data[size] = value, if out of space grow data
insert shift values to make hole at index, data[index] = value, if out of space grow data
delete shift following values forward
size return size



LinkedList
uses nodes as underlying storage

LinkedList<E>

state
Node front
size

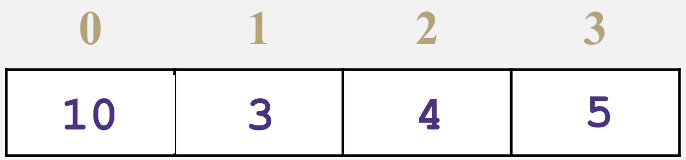
behavior
get loop until index, return node's value
set loop until index, update node's value
append create new node, update next of last node
insert create new node, loop until index, update next fields
delete loop until index, skip node
size return size

Implementing Insert

ArrayList<E>

`insert(element, index)` with shifting

`insert(10, 0)`

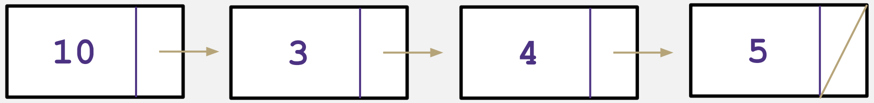


`numberOfItems = 4`

LinkedList<E>

`insert(element, index)` with shifting

`insert(10, 0)`



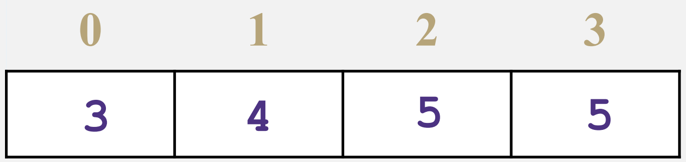
`numberOfItems = 4`

Implementing Delete

ArrayList<E>

`delete(index)` with shifting

`delete(0)`

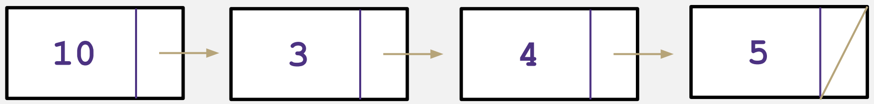


`numberOfItems = 4`

LinkedList<E>

`delete(index)` with shifting

`delete(0)`

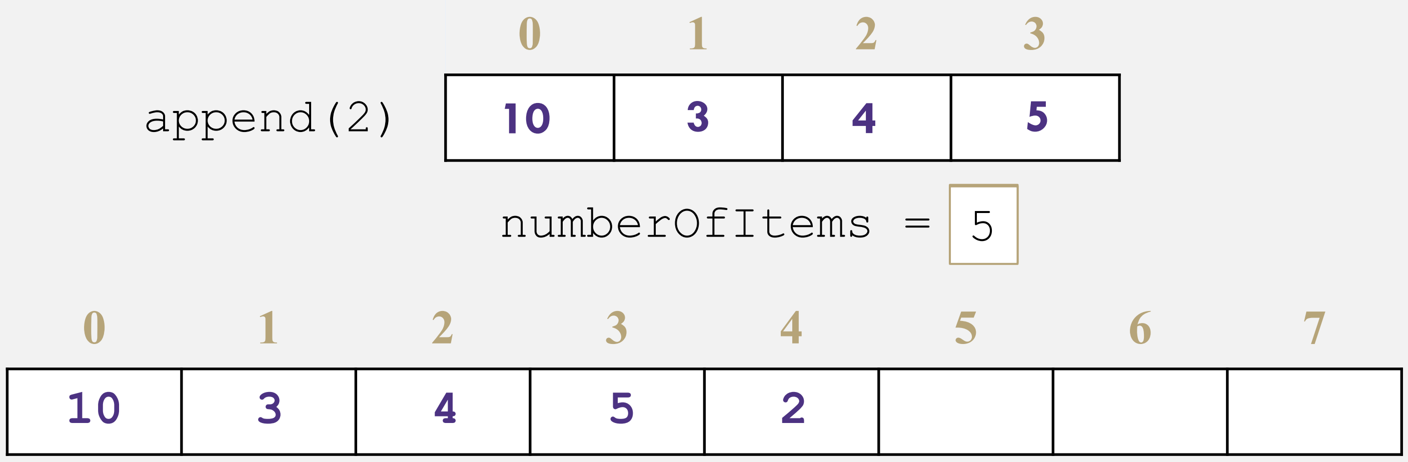


`numberOfItems = 4`

Implementing Append

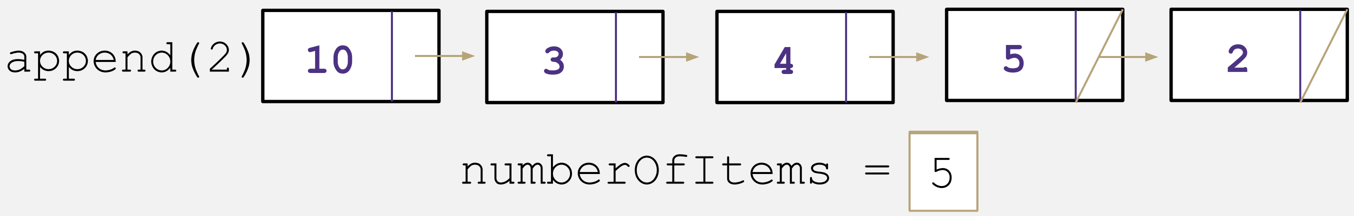
ArrayList<E>

`append(element)` with growth



LinkedList<E>

`append(element)` with growth

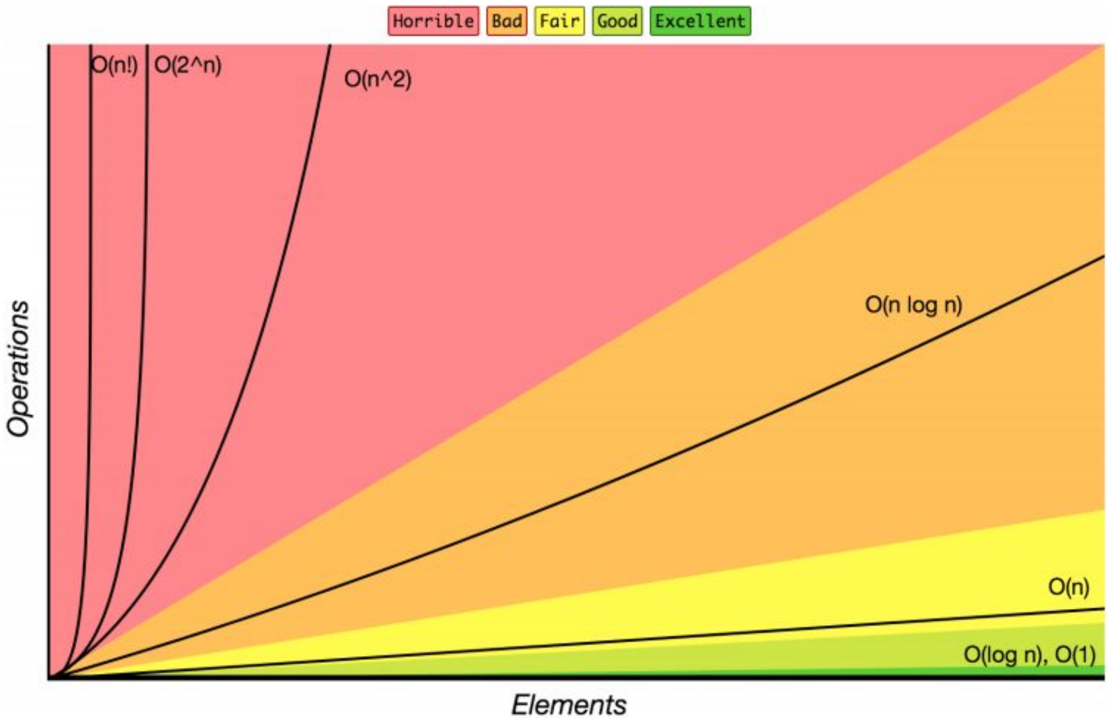


Review: Complexity Class

Note: You don't have to understand all of this right now – we'll dive into it soon.

complexity class: A category of algorithm efficiency based on the algorithm's relationship to the input size N.

Complexity Class	Big-O	Runtime if you double N	Example Algorithm
constant	O(1)	unchanged	Accessing an index of an array
logarithmic	$O(\log_2 N)$	increases slightly	Binary search
linear	O(N)	doubles	Looping over an array
log-linear	$O(N \log_2 N)$	slightly more than doubles	Merge sort algorithm
quadratic	$O(N^2)$	quadruples	Nested loops!
...	...	...	...
exponential	$O(2^N)$	multiplies drastically	Fibonacci with recursion



List ADT tradeoffs

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Last time: we used "slow" and "fast" to describe running times.

Let's be a little more precise.

Recall these basic Big-O ideas from 12X: Suppose our list has N elements

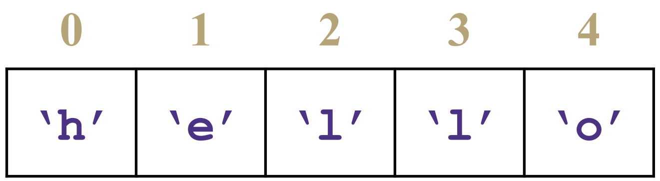
- If a method takes a constant number of steps (like 23 or 5) its running time is O(1)
- If a method takes a linear number of steps (like 4N+3) its running time is O(N)

For ArrayLists and LinkedLists, what is the O() for each of these operations?

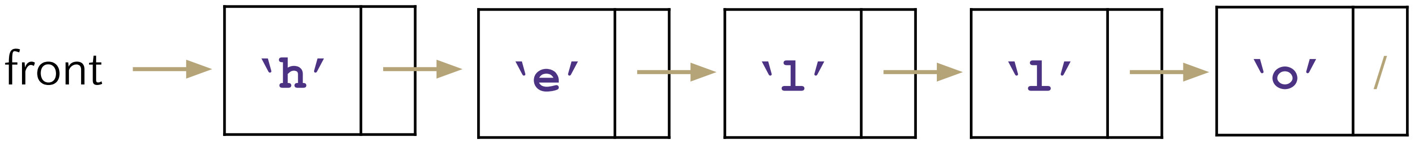
- Time needed to access Nth element
- Time needed to insert at end (what if the array is full?)

What are the memory tradeoffs for our two implementations?

`ArrayList<Character> myArr`



`LinkedList<Character> myLl`



List ADT tradeoffs

Time needed to access Nth element:

- ArrayList: O(1) constant time
- LinkedList: O(N) linear time

Time needed to insert at Nth element (if the array is full!)

- ArrayList: O(N) linear time
- LinkedList: O(N) linear time

Amount of space used overall/across all elements

- ArrayList: sometimes wasted space at end of array
- LinkedList: compact, one node for each entry

Amount of space used per element

- ArrayList: minimal, one element of array
- LinkedList: tiny bit extra, object with two fields

Design Decisions

For every ADT there are lots of different ways to implement them

Based on your situation you should consider:

- Memory vs Speed
- Generic/Reusability vs Specific/Specialized
- One Function vs Another
- Robustness vs Performance

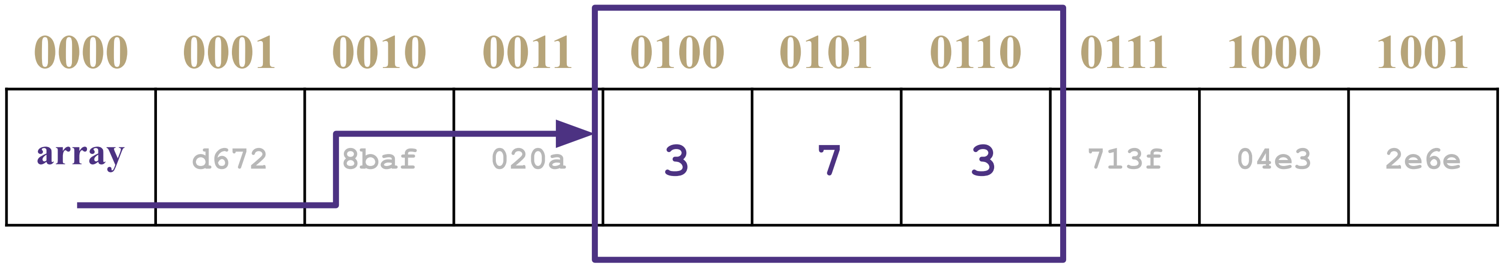
This class is all about implementing ADTs based on making the right design tradeoffs!

A common topic in interview questions!

A quick aside: Types of memory

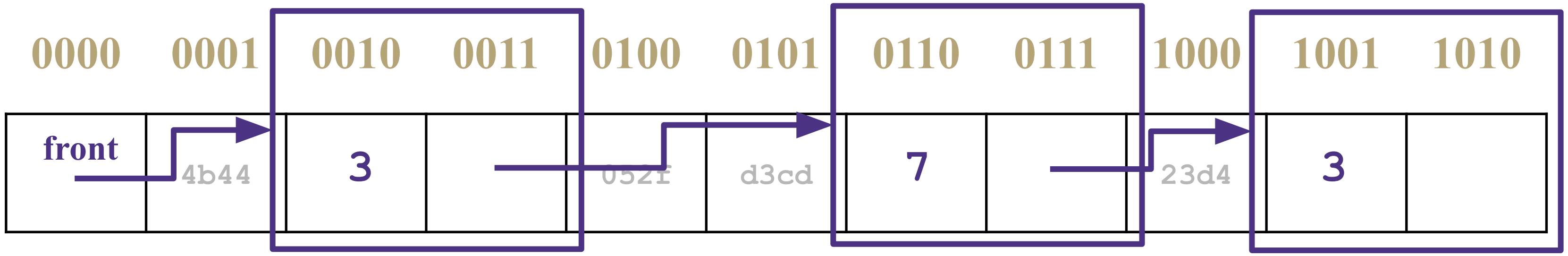
Arrays - **contiguous memory**: when the "new" keyword is used on an array the operating system sets aside a single, right-sized block of computer memory

```
int[] array = new int[3];
array[0] = 3;
array[1] = 7;
array[2] = 3;
```



Nodes- **non-contiguous memory**: when the "new" keyword is used on a single node the operating system sets aside enough space for that object at the next available memory location

```
Node front = new Node(3);
front.next = new Node(7);
front.next.next = new Node(3);
```



More on how memory impacts runtime later in this course…

Design Decisions

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Situation #1: Write a data structure that implements the List ADT that will be used to store a list of songs in a playlist.

Features to consider:

- add or remove songs from list
- change song order
- shuffle play

Why ArrayList?

- optimized element access makes shuffle more efficient
- accessing next element faster in contiguous memory

Why LinkedList?

- easier to reorder songs
- memory right sized for changes in size of playlist, shrinks if songs are removed

Design Decisions

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Situation #2: Write a data structure that implements the List ADT that will be used to store the history of a bank customer's transactions.

Features to consider:
- adding a new transaction
- reviewing/retrieving transaction history

Why ArrayList?
- optimized element access makes reviewing based on order easier
- contiguous memory more efficient and less waste than usual array usage because no removals

Why LinkedList?
- if structured with front pointing to most recent transaction, addition of transactions constant time
- memory right sized for large variations in different account history size

Design Decisions

Situation #3: Write a data structure that implements the List ADT that will be used to store the order of students waiting to speak to a TA at a tutoring center

ArrayList – optimize for addition to back
LinkedList - optimize for removal from front

Real-World Scenarios: Lists

LinkedList

- Image viewer
  - Previous and next images are linked, hence can be accessed by next and previous button
- Dynamic memory allocation
  - We use linked list of free blocks
- Implementations of other ADTs such as Stacks, Queues, Graphs, etc.

ArrayList

- Maintaining Database Records
  - List of records you want to add / delete from and maintain your order after
- Implementations of other ADTs such as Stacks, Queues, Graphs, etc.

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Questions

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Questions?

That's all!