LEC 02

CSE 373

Lists

BEFORE WE START

Fill out the 373 Start-of-Quarter survey! Max 3 min:

tinyurl.com/20SuStart

Instructor Aaron Johnston

TAs Timothy Akintilo, Brian Chan, Joyce Elauria, Eric Fan, Siddharth Vaidyanathan, Farrell Fileas, Leona Kazi, Keanu Vestil, Howard Xiao

Announcements

- Project 0 released!
  - Instructions on course website (calendar or under projects)
  - Due **Wednesday July 1 before 11:59pm PST**
  - Goals
    - Refresh 143 concepts
    - Set up IntelliJ and tools we'll use in this class (Java, GitLab, Git, Checkstyle)
    - Learn about JUnit and unit testing

- Sections start tomorrow!
  - Canvas events will be created today

- Missing permissions?
  - We'll post a form to fill out

Announcements

- Office Hours
  - This quarter, we'll run queue via Discord
    - A popular instant messaging + voice/video chat service
    - All-in-one location for OH queue, community building, getting help from peers

#oh-queue

You

@TA On Duty quick question about the definition of an ADT @dubs

@ your project partner or anyone else you're working with

ping all TAs currently "on duty" in OH

briefly summarize your question

Sure! Let's all discuss in this Zoom meeting:

TA

Why Discord?

- Build community!
  - Survey results: COVID has made us distant ☹
  - Social channels for hanging out, meeting people, finding partners
    - These are your space! Not managed by course staff
- Seamless Queueing
  - Students reported Zoom waiting rooms and spreadsheets were clunky
  - Hang around, get a notification when a TA is ready
- Be In the Room Where It Happens
  - Chat while you’re waiting!
    - Public channels: ask if anyone has a similar issue, see who else is on the queue and reach out

Using Discord

- Two ways to participate:

1 Create Discord Account

- Enter your email
- Stay logged in for the quarter
- Easier to meet people and build community

OR

2 Join Anonymously

- Temporary display name, no other info
- Account disappears when you close window
- Use Discord as simple, anonymous queue service; get helped over Zoom

- Discord is a 3rd-Party App
  - You do NOT need to enter any personal information to participate in OH
  - But you are welcome to make an account or use an existing one
  - Have fun, but be respectful and welcoming

Announcements

- Office Hours
  - Discord server invite will be posted later today
  - Office Hours will start this Friday, June 26th
  - Note: TA continually monitor Piazza, only monitor Discord during OH

- Instructor meeting link added to Staff Page
  - Schedule a 1:1 for anything! Course concerns, taking these concepts beyond 373, interviews/job advice, meaning of life, etc.

- Survey results: Anxious about 143 material?
  - Don’t worry! ☺ P0 is all about helping you get back up to speed!
  - We’ll publish an additional review guide today

Lecture Outline

- **Runtime Analysis**
- The List ADT
- Design Decisions

Learning Objectives

After this lecture, you should be able to...

- *(143 Review)* Determine whether simple code belongs to the constant, linear, or quadratic complexity classes
- Distinguish the List ADT from ArrayList and LinkedList implementations
- Compare the runtime of certain operations on ArrayList and LinkedList, based on how they're implemented
- Describe the process of making design decisions

Runtime Analysis

- What does it mean for a data structure to be ”slow” or “fast”?

- We could just run and measure the (wallclock) time!
  - Why won’t that work?
    - Different hardware could affect speed
    - What other programs are running?
    - Speed affected by the input given

- Our general approach:
  - Count how many “steps” a program takes to execute on an input of size N

143 Review "Big Oh"

- **Efficiency**: measure of computing resources used by code
  - Could be time (most common), space/memory taken up, etc.

- We measure runtime in proportion to the input data size, N
  - **Growth Rate**: change in runtime as N gets bigger

- Assume:
  - Every Java statement takes the same amount of time to run
  - Method call runtime: total of statements in its body
  - Loop runtime: (number of repetitions) x (total of its body)

143 Review "Big Oh"

```
a = b + 1;
```

Runs 1 statement
Constant

```
for (int i = 0; i < N; i++) {
  data[i] = a;
}
```

Runs N statements
Linear

```
for (int i = 0; i < N; i++) {
  for (int j = 0; j < N; j++) {
    data1[i] = a;
    data2[i] = b;
    data3[i] = c;
  }
}
```

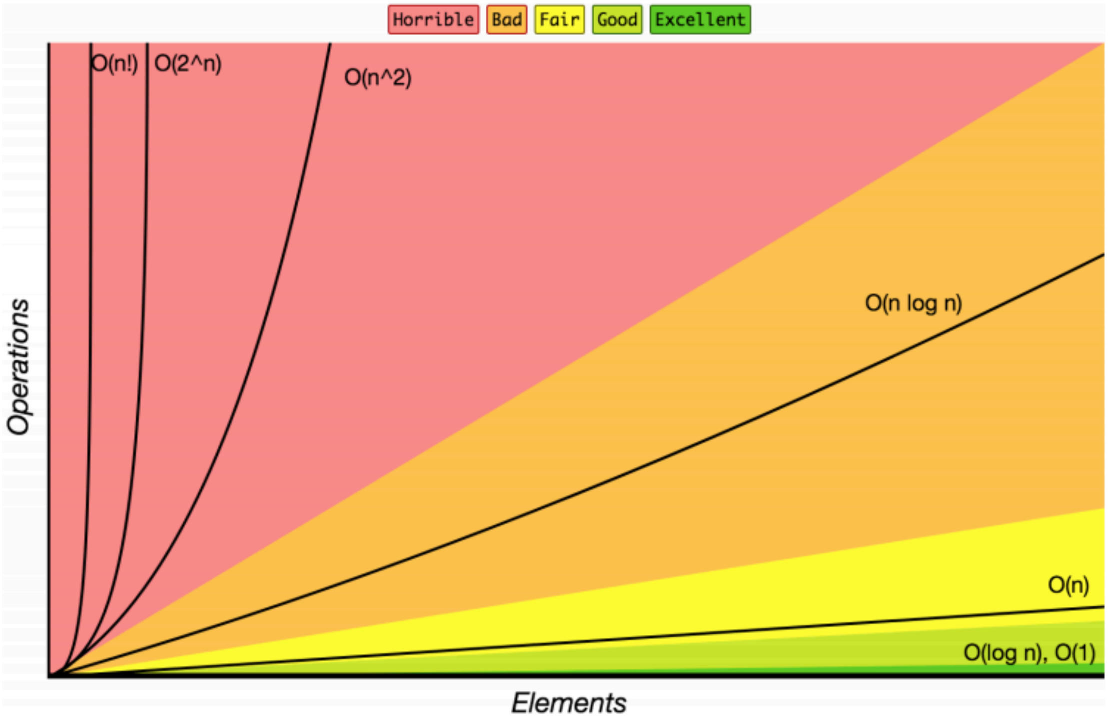
Runs $3N^2$ statements
Quadratic

- We ignore constants like 3 because they are tiny next to N or N^2
- We say that this algorithm runs "on the order of" N^2
- or **O(N^2)** for short ("**Big-Oh** of N squared")

143 Review Complexity Class

- **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
constant	**O(1)**	**unchanged**
logarithmic	$O(\log_2 N)$	increases slightly
linear	**O(N)**	**doubles**
log-linear	$O(N \log_2 N)$	slightly more than doubles
quadratic	$\mathbf{O(N^2)}$	**quadruples**
…	…	…
exponential	$O(2^N)$	multiplies drastically

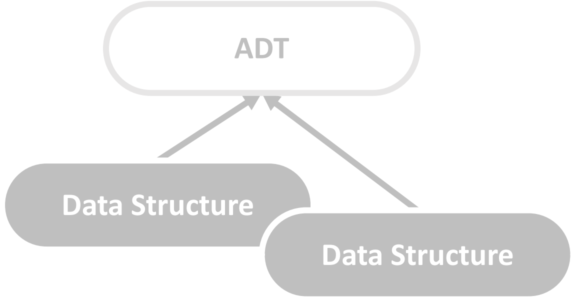


Lecture Outline

- Runtime Analysis
- **The List ADT**
- Design Decisions

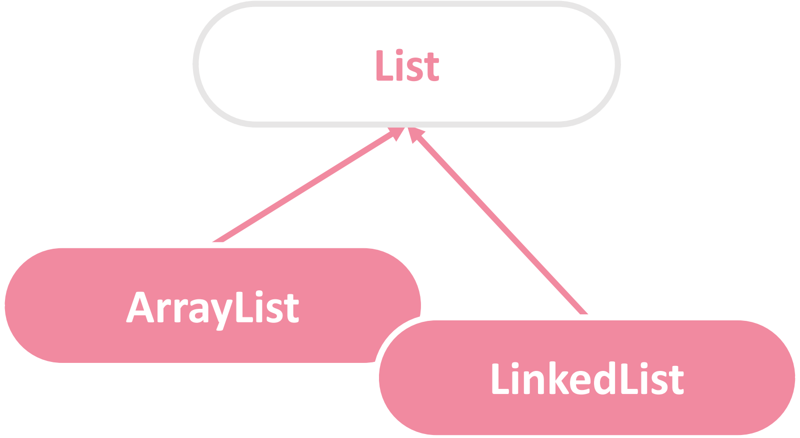
Review ADTs: Abstract Data Types

- An **abstract data type** is a data type that does not specify any one implementation.
  - Think of this as an agreement: about *what* is provided, but not *how*.



- **Data structures** implement ADTs.
  - **Resizable array** can implement List, Stack, Queue, Deque, PQ, etc.
  - **Linked nodes** can implement List, Stack, Queue, Deque, PQ, etc.

For Example:



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 variable size defined as the number of elements in the list
- Elements can be added to or removed from any position in the list

Relation to code/mental image of a list:

```
List<String> names = new ArrayList<>();  // []
names.size();                            // evaluates to 0
names.add(”Timothy");                    // [“Timothy”]
names.add(”Siddharth");                  // [“Timothy, Siddharth”]
names.insert(”Leona”, 0);                // [“Leona”, “Timothy”, “Siddharth”]
names.size();                            // evaluates to 3
```

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
add(item) add item to end of list
insert(item, index) add item at index
delete(index) delete item at index
size() count of items

[88.6, 26.1, 94.4]

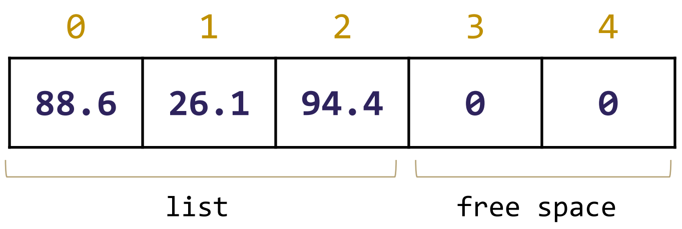
ArrayList<E>

State

```
data[]
size
```

Behavior

```
get return data[index]
set data[index] = value
add 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<E>

State

```
Node front;
size
```

Behavior

```
get loop until index, return node's value
set loop until index, update node's value
add 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
```

Case Study: Let's zoom In On ArrayList

- How do Java / other programming languages implement ArrayList to achieve all the List behavior?
- On the inside:
  - stores the elements **inside an array** (which has a fixed capacity) that typically has more space than currently used (For example when there is only 1 element in the actual list, the array might have 10 spaces for data),
  - stores all of these elements at the front of the array and **keeps track of how many there are** (the size) so that the implementation doesn't get confused enough to look at the empty space. This means that sometimes we will have to do a lot of work to shift the elements around.

List View

[“Leona”, “Timothy”, “Siddharth”]

ArrayList View

[“Leona”, “Timothy”, “Siddharth”, null, null, null]

Implementing ArrayList

ArrayList<E>

State

data[]
size

Behavior

<u>get</u> return data[index]
<u>set</u> data[index] = value
<u>add</u> data[size] = value, if out of space grow data
<u>insert</u> shift values to make hole at index, data[index] = value, if out of space grow data
<u>delete</u> shift following values forward
<u>size</u> return size

`insert(element, index)` with shifting

`insert("d", 0)`

0	1	2	3
d	b	c	

size = 4

`delete(index)` with shifting

`delete(0)`

0	1	2	3
d	a	b	c

size = 3

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Should we overwrite index 3 with null?

Briefly explain why or why not.

ArrayList<E>

State
- data[]
- size

Behavior
- get return data[index]
- set data[index] = value
- add 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

`insert(element, index)` with shifting

`insert("d", 0)`

d	a	b	c

size = 4

`delete(index)` with shifting

`delete(0)`

0	1	2	3
a	b	c	c

size = 3

Implementing ArrayList

ArrayList<E>

State
- data[]
- size

Behavior
- get return data[index]
- set data[index] = value
- add 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

`append(element)` with growth

`append(2)`

0	1	2	3
10	3	4	5

`numberOfItems = 5`

0	1	2	3	4	5	6	7
				2			

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Which operations will be much faster for LinkedList than ArrayList? Briefly explain why.

LIST ADT

State

Set of ordered items
Count of items

Behavior

get(index) return item at index
set(item, index) replace item at index
add(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<E>

State

```
data[]
size
```

Behavior

```
get return data[index]
set data[index] = value
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delete shift following values forward
size return size
```

LinkedList<E>

State

```
Node front;
size
```

Behavior

```
get loop until index, return node's value
set loop until index, update node's value
add 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
```

Lecture Outline

- Runtime Analysis
- The List ADT
- **Design Decisions**

Design Decisions

- For every ADT, many ways to implement
- Based on your situation you should consider:
  - Speed vs Memory Usage
  - 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

Poll Everywhere

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Design Decisions

- Dub Street Burgers is implementing a new system to manage orders
- When an order comes in, it's placed at the end of the set of orders
- Food is prepared in approximately the same order it was requested, but sometimes orders are fulfilled out of order

- Let's represent tickets using the List ADT. **What implementation should we use? Why?**

What implementation should we use? Why?

- ArrayList
  - Creating a new order is very fast (as long as we don't have to resize)
  - Cooks can see any given order easily
- LinkedList
  - Creating an order is slower (have to iterate through whole list)
  - We'll mostly be removing from the front of the list, which is fast because it requires no shifting

Comparing ADT Implementations: List

	ArrayList	LinkedList
`add (front)`	linear	constant
`remove (front)`	linear	constant
`add (back)`	(usually) constant	linear
`remove (back)`	constant	linear
`get`	constant	linear
`put`	linear	linear

- Important to be able to come up with this, and understand why
- But only half the story: to be able to make a design decision, need the context to understand which of these we should prioritize

Design Decisions

- Both ArrayList and LinkedList have pros and cons, neither is strictly better than the other
- The Design Decision process:
  - **Evaluate** pros and cons
  - **Decide** on a design
  - **Defend** your design decision
- This is a major objective of the course!