CSCI 136: Data Structures and Advanced Programming

Lecture 17

Linear structures, part 2

Instructor: Dan Barowy

Williams

Topics

- Stack data structure
- Queue ADT
- Queue data structure
- Resubmission procedure

Your to-dos

1. Lab 6 (partner lab), **due Tuesday 11/1 by 10pm**. (two weeks!)
2. Review readings for midterm.

Announcements

- Colloquium: **What I Did Last Summer (Research)**, 2:35pm in Wege Auditorium with **cookies**.
- Practice midterm posted on the course website.
- TA feedback.

Announcements

Please **consider being a TA** next semester (especially for this class!)

Applications **due Friday, October 28**.

https://csci.williams.edu/tatutor-application/

Queue ADT

A **queue** is an **abstract data type** that stores a collection of **any type of element**. A queue **restricts which elements are accessible**: elements may only be added to the "**end**" of the collection and elements may only be removed from the "**front**" of a collection. The "**enqueue**" operation places an element at the end of a queue while a "**dequeue**" operation removes an element from the front.

Queue ADT

Queue ADT

Also sometimes referred to as a **FIFO**: **"first in, first out."**

(a stack would be an annoying way to process a line at Starbucks!)

Frequently used as a **buffer** to hold work **to do later**.

We also frequently include a "**peek**" operation that lets us look at an element on the top of a queue without removing it, and "**size**" and "**isEmpty**" operations that let us check how many elements are stored and whether a queue stores zero elements, respectively.

Queue implementations

QueueArray

A **QueueArray** is a queue implemented using an **array** for element storage.

Pros: **enqueue** and **dequeue** are **O(1)** operations.

Cons: data structure has a maximum **capacity**.

Queue implementations

QueueVector

A **QueueVector** is a queue implemented using a **Vector** for element storage.

Pros: **enqueue** and **dequeue** are amortized **O(1)** operations. There is no maximum capacity.

Cons: Most of the time, they take **O(1)** time, but occasionally--when the underlying array needs to grow--an **O(n)** cost is incurred. This may be fine for most applications, but if the application cannot tolerate wide variation in time, this is a bad choice. Also, unless the underlying array is completely full, **Vectors waste some space**.

Queue implementations

QueueList

A **QueueList** is a queue implemented using a **List** (usu. **DLL** or **CL**) for element storage.

Pros: enqueue and dequeue are **O(1)** operations. There is no maximum capacity. **enqueue** and **dequeue** costs are predictable (always the same), unlike **QueueVector**.

Cons: because of the way computer hardware is implemented, a **QueueList**'s constant-time cost is likely to be much higher than a **QueueVector**'s. So a **QueueList**'s performance may be more predictable than a **QueueVector**, but it will likely be slower on average.

Other queue-like ADTs

One very useful and interesting variant of the Queue ADT is the **Priority Queue ADT**. We'll talk about priority queues after the midterm!

Resubmission procedure

Resubmission procedure

Remember: the goal of this course is mastery.

Resubmission procedure

Allows you to earn **up to 50% of the lost points**.

E.g., **if you got a 50%** on the midterm, **you can get a 75%** on resubmission.

Midterm is 25% of your final grade. **This is worth doing!**

Resubmission procedure

1. You have **until the end of reading period**.
2. Resubmission **must include both** the **original work** and the **new submission**.
3. Must be accompanied by an **explanation document**, written in plain English.

Resubmission procedure

Explanation document **must identify**:

1. **What** the mistake is.
2. **How** you fixed the mistake.
3. **Why** the new version is correct.

Resubmission procedure

Resubmit code **electronically**
(i.e., using git).

Resubmit exam **on paper**
(i.e., hand it to me or put in mailbox).

Resubmission procedure

Sample from CS334:

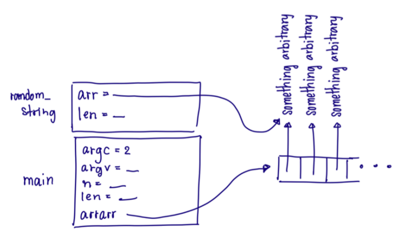
2. Troubleshooting
My fix was slightly wrong. Righr before calling *random_string*(), I added

```
char * arrarr[i] = malloc(sizeof(char)*MAXLEN);
```

when what I should have added is

```
arrarr[i] = malloc(sizeof(char)*MAXLEN);
mcheck(arrarr[i]);
```

There is no need for "char *" because I am not declaring *arrarr*.
I got my explanation and drawing wrong. In my drawing, I had *arrarr*[*i*] pointing back to a call stack because I thought the program would automatically allocate memory on a call stack if we did not *malloc*(). What I should have said is that without allocating sub-array *arrarr*[*i*], the address currently living in the sub-array is arbitrary so the value referred to by the sub array is also arbitrary. When we call *memset*() or manipulating *arrarr*[*i*] in *random_string*(), we are likely to get memory errors. Below is what I should have drawn.



Iterators

What do the following have in common?

```
double[] a
// … initialize a …
double sum = 0.0;
for (int i = 0; i < a.length; i++) {
  sum += a[i];
}
```

```
List<Double> ls = new SinglyLinke
// … initialize ls …
double sum = 0.0;
for (int i = 0; i < ls.size(); i
  sum += ls.get(i);
}
```

```
Stack<Double> s = new StackVect
// … initialize s …
double sum = 0.0;
while (!s.isEmpty()) {
  sum += s.pop();
}
```

Iteration

Iteration is the **repetition of a process** in order to generate a (possibly unbounded) **sequence of outcomes**. Each step in an iteration performs the given process **once**; the result of each step is the **starting point** of the **next step**.

Each program iterates

```
double[] a
// … initialize a …
double sum = 0.0;
for (int i = 0; i < a.length; i++) {
  sum += a[i];
}
```

100	101	102	103
0	1	2	3

i: 0   sum: 0

Each program iterates

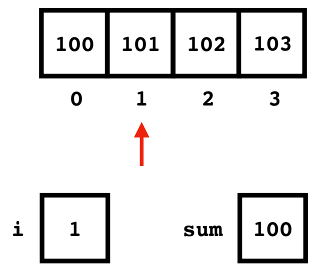
```
double[] a
// … initialize a …
double sum = 0.0;
for (int i = 0; i < a.length; i++) {
  sum += a[i];
}
```

100	101	102	103
0	1	2	3

i: 0   sum: 100

Each program iterates

```
double[] a
// … initialize a …
double sum = 0.0;
for (int i = 0; i < a.length; i++) {
  sum += a[i];
}
```



Each program iterates

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// … initialize a …
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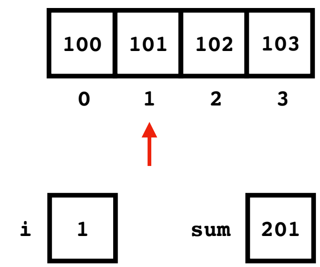

Each program iterates

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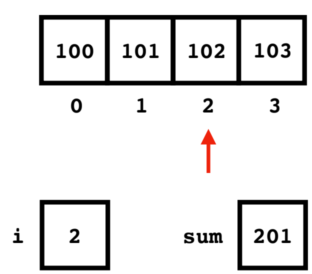

Each program iterates

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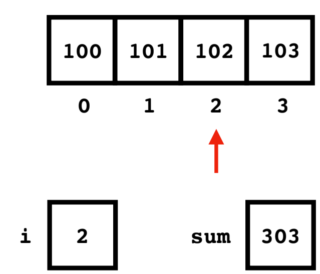

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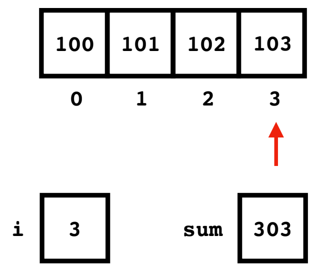

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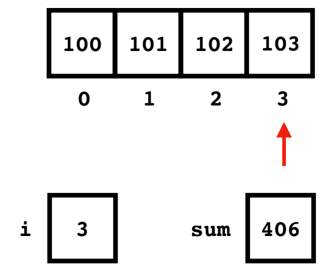

Each program iterates

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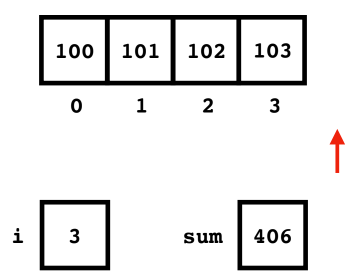
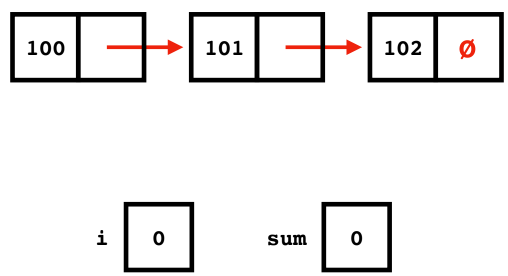


Iteration is terminated!

Each program iterates

```
List<Double> ls = new SinglyLinkedList<>();
// … initialize ls …
double sum = 0.0;
for (int i = 0; i < ls.size(); i++) {
  sum += ls.get(i);
}
```



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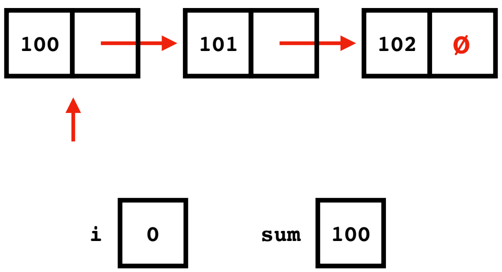

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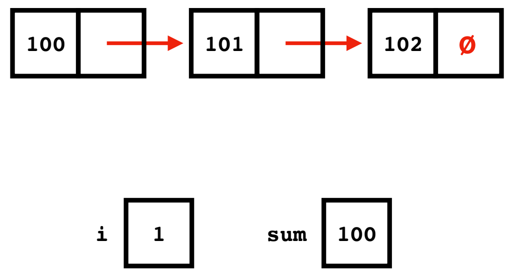

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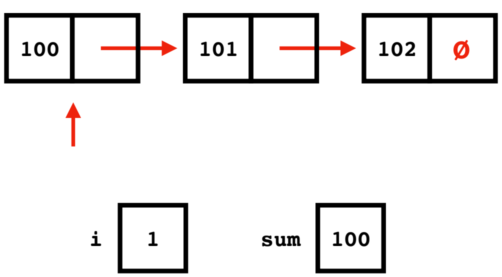

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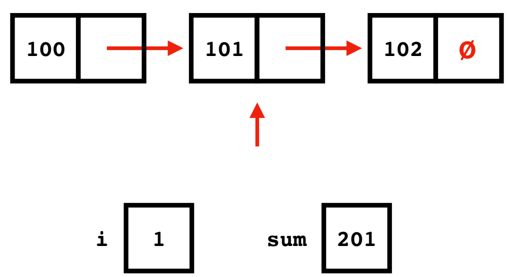

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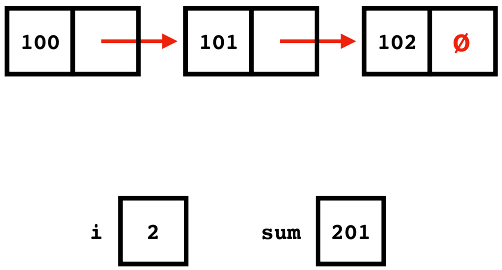

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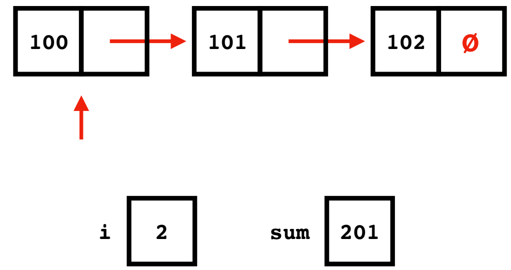

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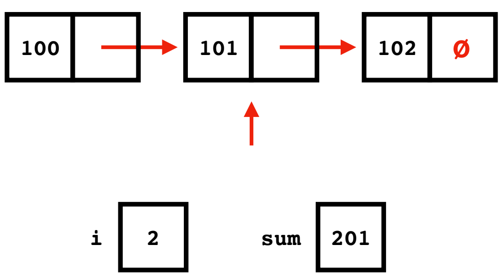

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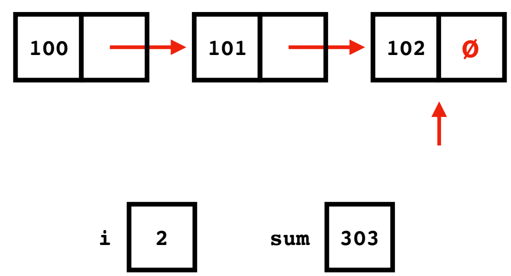

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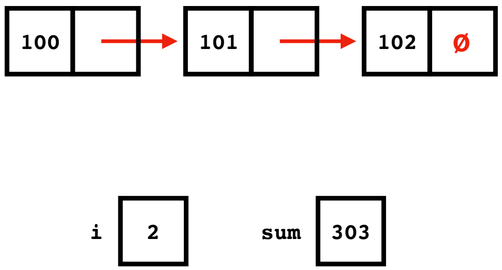
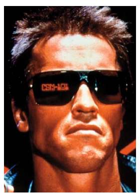
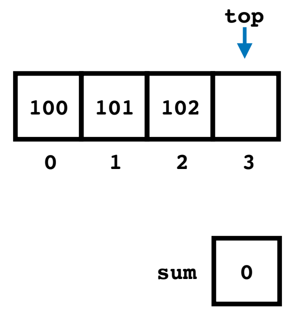




Iteration is terminated!

Each program iterates

```
Stack<Double> s = new StackVector<>();
// … initialize s …
double sum = 0.0;
while (!s.isEmpty()) {
  sum += s.pop();
}
```



Each program iterates

```
Stack<Double> s = new StackVector<>();
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  sum += s.pop();
}
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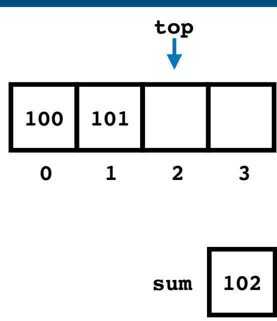

Each program iterates

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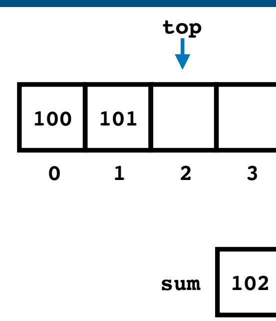

Each program iterates

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double sum = 0.0;
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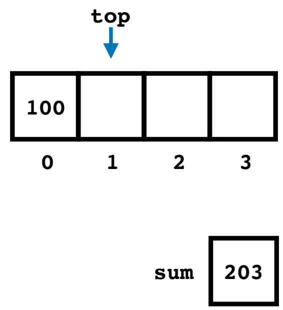

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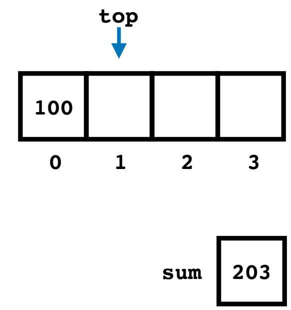

Each program iterates

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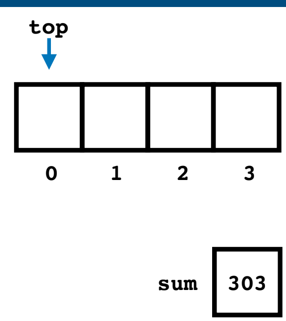

Each program iterates

```
Stack<Double> s = new StackVector<>();
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double sum = 0.0;
while (!s.isEmpty()) {
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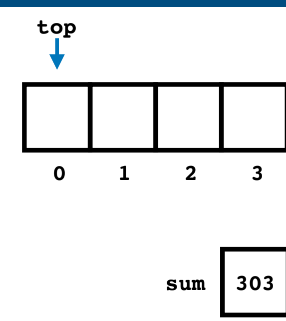

Iteration is terminated!

Essentially the same algorithm!

```
double[] a
// … initialize a …
double sum = 0.0;
for (int i = 0; i < a.length; i++) {
  sum += a[i];
}
```

```
List<Double> ls = new SinglyLinkedList<>();
// … initialize ls …
double sum = 0.0;
for (int i = 0; i < ls.size(); i++) {
  sum += ls.get(i);
}
```

```
Stack<Double> s = new StackVector<>();
// … initialize s …
double sum = 0.0;
while (!s.isEmpty()) {
  sum += s.pop();
}
```

But the code looks different.

Problems

- **Different data structures** yield **different code for same algorithm**.
- **Data hiding** potentially causes **efficiency problems**.
- **Inspecting** data structure "from the outside" can **change the state** of a data structure (e.g., `pop()`'ing a `Stack`).

What if I told you that you could solve

all of these problems with **abstraction**?

Iteration abstraction to the rescue.

```
double[] a
// … initialize a …
double sum = 0.0;
for (double d : a) {
  sum += d;
}
```

```
List<Double> ls = new SinglyLinkedList<>();
// … initialize ls …
double sum = 0.0;
for (double d : ls) {
  sum += d;
}
```

```
Stack<Double> s = new StackVector<>();
// … initialize s …
double sum = 0.0;
for (double d : s) {
  sum += d;
}
```

Brought to you by **Iterators**.

Iterators are a really good idea.

- Invented by Barbara Liskov in 1974.
- Incidentally, **abstract data types** were also invented by Barbara Liskov in 1974.
- (1974 was a good year!)
- Both debuted in an influential PL named **CLU**.
- Barbara won the **Turing Award in 2008** for this work and more.

Remember this from Python?

```
for num in nums:
   # do something
```

Java has it too!

```
for (int num : nums) {
  // do something
}
```

(admittedly, it is less pretty in Java)

This is called a "for-each loop"

Recap & Next Class

Today:

Queue ADT

Queue implementation

Resubmissions

Next class:

Iterators

Search