Queues and Unit Testing

Shreya Shankar

Stanford CS 106B

3 July 2018

Based on slides created by Ashley Taylor, Marty Stepp, Chris Gregg, Keith Schwarz, Julie Zelenski, Jerry Cain, Eric Roberts, Mehran Sahami, Stuart Reges, Cynthia Lee, and others.

Recap

Big O

- Idea: measures algorithmic **efficiency**
  - How *long* does the program take to run?
- Algorithms are better if they take less time
- Number of statements in code can depend on how large the input is – we normally say the input size is N
- Only the biggest power of N matters
- To calculate big O, work from innermost indented code out

Example

Q: What is the big O?

```
Vector<int> v;
for (int x = 1; x <= N; x += 2) {
    v.add(x);
}
while (! v.isEmpty()) {
    cout << v.remove(0) << endl;
}
```

A:

Example

Q: What is the big O?

```
Vector<int> v;
for (int x = 1; x <= N; x += 2) {
    v.add(x);
}
while (! v.isEmpty()) {
    cout << v.remove(0) << endl;
}
```

A: $O(n^2)$

Stacks

- `stack`: ADT that only allows a user to push an element and peek or pop the last element
  - "Last-in, first-out"
  - O(1) for these operations
- Basic `stack` operations:
  - `push`: add an element to the end of the stack
  - `pop`: remove and return the last element in the stack
  - `peek`: return (but do not remove) the last element in the stack

Queues

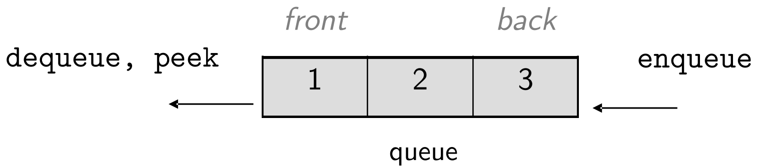
Motivation

- There is behavior that stacks fail to model well
  - What if we want to remove from front instead of from back?
- Can we model first-in, first-out behavior using other ADTs?
  - Vector: removing from the beginning of a list is an O(n) operation
  - Stack: need two stacks to get the first element (food for thought: how to do this?)
  - Grid: nah
- So, we need a new ADT...

Rear of Queue
Front of Queue
next...
PAY HERE

Queues

- queue: ADT that retrieves elements in the order they were added
  - First-in, First-out ("FIFO")
  - Elements are stored in order of insertion, no indexes
  - Can add only to the end of a queue and can only examine or remove the front
- Basic queue operations:
  - enqueue: add an element to the back
  - dequeue: remove the front element
  - peek: examine the front element



Class methods

```
#include "queue.h"
```

`q.dequeue()`	O(1)	removes **front** value and returns it; throws error if queue is empty
`q.enqueue(value)`	O(1)	places given value at **back** of queue
`q.isEmpty()`	O(1)	returns true of queue has no elements
`q.peek()`	O(1)	returns **front** value without removing; throws an error if queue is empty
`q.size()`	O(1)	returns number of elements in queue

Table 1: The Queue class in Stanford's C++ libraries.

- Food for thought: what *isn't* an O(1) operation?

Example

```
Queue<int> q;                   // {} front -> back
q.enqueue(42);                  // {42}
q.enqueue(-3);                  // {42, -3}
q.enqueue(17);                  // {42, -3, 17}
cout << q.dequeue() << endl; // 42 (q is {-3, 17})
cout << q.peek() << endl;     // -3 (q is {-3, 17})
cout << q.dequeue() << endl; // -3 (q is {17})
```

Applications

- Real-world examples
  - Middle school lunch lines (no cutting!)
  - Escalators (when someone is taking up the whole step)
  - Anything first-come-first-serve
- Computers
  - Sending jobs to a printer
  - Uploading photos on social media
  - Call services – being on hold

Exercise

Q: What is the output of the following code?

```
Queue<int> queue;
for (int i = 1; i <= 6; i++) {
    queue.enqueue(i);
} // {1, 2, 3, 4, 5, 6}

for (int i = 0; i < queue.size(); i++) {
    cout << queue.dequeue() << " ";
}
cout << queue << " size " << queue.size() << endl;
```

A. `1 2 3 4 5 6 {} size 0`
B. `1 2 3 {4, 5, 6} size 3`
C. `1 2 3 4 5 6 {1, 2, 3, 4, 5, 6} size 6`
D. *none of the above*

Exercise

Q: What is the output of the following code?

```
Queue<int> queue;
for (int i = 1; i <= 6; i++) {
    queue.enqueue(i);
} // {1, 2, 3, 4, 5, 6}

for (int i = 0; i < queue.size(); i++) {
    cout << queue.dequeue() << " ";
}
cout << queue << " size " << queue.size() << endl;
```

A. 1 2 3 4 5 6 {} size 0

B. 1 2 3 {4, 5, 6} size 3

C. 1 2 3 4 5 6 {1, 2, 3, 4, 5, 6} size 6

D. *none of the above*

Exercise

Q: Write a function **stutter** that accepts a queue of integers and replaces every element with two copies of itself. For example, {`1, 2, 3`} becomes {`1, 1, 2, 2, 3, 3`}.

Exercise

Q: Write a function **stutter** that accepts a queue of integers and replaces every element with two copies of itself. For example, {`1, 2, 3`} becomes {`1, 1, 2, 2, 3, 3`}.

```
void stutter(Queue<int>& q) {
    int size = q.size();
    for (int i = 0; i < size; i++) {
        int n = q.dequeue();
        q.enqueue(n);
        q.enqueue(n);
    }
}
```

Helpful hints for queues

- Don't use `size()` directly

```
int size = q.size();
for (int i = 0; i < size; i++) {
    // do something with q.dequeue();
    // (including possibly re-adding it to the
        queue)
}
```

- As with stacks, must pull contents out of queue to view them

```
// process (and destroy) an entire queue
while (!q.isEmpty()) {
    // do something with q.dequeue();
}
```

More Queues

Mixing stacks and queues

How can we reverse the order of elements in a queue?

```
Queue<int> q {1, 2, 3};  // q={1, 2, 3}
Stack<int> s;

while (!q.isEmpty()) {   // transfer queue to stack
    s.push(q.dequeue()); // q={} s={1, 2, 3}
}

while (!s.isEmpty()) {   // transfer stack to queue
    q.enqueue(s.pop());  // q={3, 2, 1} s={}
}

cout << q << endl;       // {3, 2, 1}
```

Exercise

Q: Write a function **mirror** that accepts a queue of strings and appends the queue's contents to itself in reverse order. For example, {`"a", "b", "c"`} becomes {`"a", "b", "c", "c", "b", "a"`}.

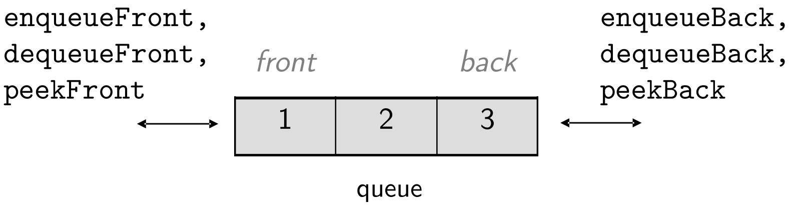
Exercise

Q: Write a function **mirror** that accepts a queue of strings and appends the queue's contents to itself in reverse order.

```
void mirror(Queue<string>& q) {
    Stack<string> s;
    int size = q.size();
    for (int i = 0; i < size; i++) {
        string str = q.dequeue();
        s.push(str);
        q.enqueue(str);
    }
    while (!s.isEmpty()) {
        q.enqueue(s.pop());
    }
}
```

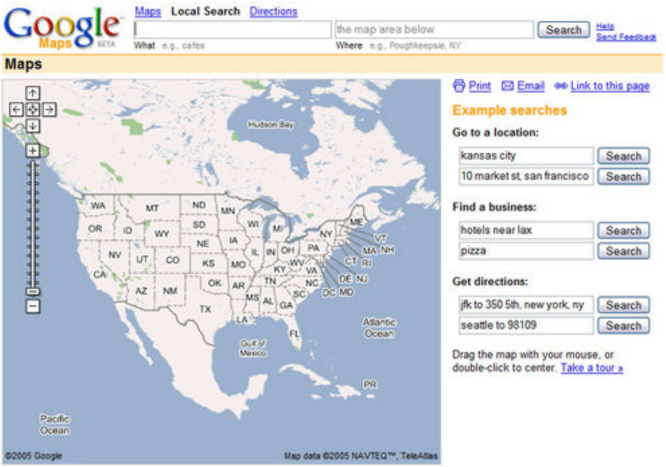
Deques

- deque: double-ended queue (pronounced "deck")
  - Can add/remove from either end
  - Combines many of the benefits of stack and queue
- Basic deque operations:
  - `enqueueFront, enqueueBack`
  - `dequeueFront, dequeueBack`
  - `peekFront, peekBack`
- Get queue and stack functionality in one data structure!



Unit Testing

Early Google Maps



the map area below

Example searches

Go to a location:

kansas city — Search

10 market st, san francisco — Search

Find a business:

hotels near lax — Search

pizza — Search

Get directions:

jfk to 350 5th, new york, ny — Search

seattle to 98109 — Search

Drag the map with your mouse, or double-click to center. Take a tour »

Evolution of Google Maps: real-world technology

- Version 1: could only look up a city in the US and see roads in it – "paper atlas in living form" (Recode article)
- Then, added functionality to calculate directions from one place to another
- Added ability to search for local businesses
- Added satellite imagery for people to view their own houses, making Maps very popular
- A couple years into development, the team completely rewrote all code to make it run faster
- Problems: How to make sure all this code is functional? How to make sure functionality persists throughout all these changes?

Motivation

- Code in the real world:
  - You are not the only one reading the code you write
  - Code is frequently updated to offer new functionality, fix old bugs, etc.
  - We often know what functionality we need, and we want to make sure our code hits all the "edge cases"
- **Unit testing** is a method for testing small pieces or "units" of source code for a larger piece of software
- Usually a series of functions to run
- Benefits of unit testing:
  - Limits your code to only what is necessary and finds bugs early
  - Easily preserves functionality when code is changed

Unit testing basics

- Unit tests are usually a list of functions in a file, where each function tests a **small piece of functionality**
    - We don't want to test lots of things in one unit test function
- Each unit test (function) has a way of indicating "pass" or "failure"
- Each programming language has its own style of unit testing
- Unit tests are usually designed before code is written
- Unit testing is usually automated – before new code can enter the codebase, the test file is run and all unit tests must pass

Common unit test macros

- `assert`: throws error if condition inside assert statement is false

```
void checkNumStreetsInBigCities(Location &loc) {
    int numStreets = getNumStreets(loc);
    assert(numStreets > 100); // will crash program
        if false
}
```

- `expect`: displays error when condition inside expect statement is false, but other tests continue to run
- Use `assert` when test is critical, `expect` otherwise

Exercise

Recall grids: Write a function **getPossibleMoves** that accepts a grid and a row/column pair (row, col) as parameters, and returns a vector of empty locations that a knight can legally move to from (row, col).

- Recall that a knight makes an "L" shaped move, going 2 squares in one dimension and 1 square in the other.
- `getPossibleMoves(board, 1, 2)` returns `Vector<Point>` `{(0, 0), (2, 0), (3, 3), (2, 4)}`

Exercise

`getPossibleMoves(board, 1, 2)` returns `Vector<Point>`
`{(0, 0), (2, 0), (3, 3), (2, 4)}`

	0	1	2	3	4	5	6	7
0	🟨				"king"			
1			"knight"					
2	🟨				🟨			
3		"rook"		🟨				
4								
5								
6								
7								

Exercise

Step one: think about all subunit functionalities (for lecture purposes, we'll list a few)

1. Need to be able to process all valid moves from a given location
2. Need to make sure our valid moves don't have our pieces in them
3. Need to make sure our valid moves processed don't go out of bounds
4. Need to make sure user is passing a location in bounds

Solution

```
Vector<Point> getPossibleMoves(Grid<string>& board, int row, int col) {
    Vector<Point> validMoves;
    if (!board.inBounds(row, col) || board[row][col] != "knight") return validMoves;

    for (int xDir = -1; xDir <= 1; xDir += 2) {
        for (int yDir = -1; yDir <= 1; yDir += 2) {
            for (int xLen = 1; xLen <= 2; xLen++) {
                int yLen = 3 - xLen;
                Point point = (xLen * xDir, yLen * yDir);
                if (board.inBounds(row + point.getX(), col + point.getY())
                    && board[row + point.getX()][col + point.getY()] == "")
                        validMoves.add(point);
            }
        }
    }

    return validMoves;
}
```

Testing exercise

Prototype for functionality 1:

```
const Grid<string> TEST_BOARD;

void checkNumPossibleMoves() {
    /* Get possibleMoves: vector of possible locations
        knight could end up at */
    Vector<Point> possibleMoves = getPossibleMoves
        (TEST_BOARD, 1, 2);

    // No more than 8 possible locations to move to
    assert(possibleMoves.size() <= 8);
}
```

Testing exercise

Prototype for functionality 2:

```
const Grid<string> TEST_BOARD;
void checkNoPiecesInPossibleMoves() {
    Vector<Point> possibleMoves = getPossibleMoves
        (TEST_BOARD, 1, 2);
    Vector<Point> currentLocs =
        getCurrentPieceLocations();

    // Check to make sure possibleMoves doesn't contain
        our pieces
    for (Point pLoc: possibleMoves) {
        for (Point cLoc: currentLocs) {
            assert(pLoc != cLoc);
        }
    }
}
```

Testing exercise

Prototype for functionality 3:

```
const Grid<string> TEST_BOARD;

void checkPossibleMovesInBounds() {
    Vector<Point> possibleMoves = getPossibleMoves
        (TEST_BOARD, 1, 2);

    // Check to make sure possibleMoves are in bounds
    for (Point pLoc: possibleMoves) {
        assert(TEST_BOARD.inBounds(pLoc.getX(),
            pLoc.getY()));
    }
}
```

Testing exercise

Prototype for functionality 4:

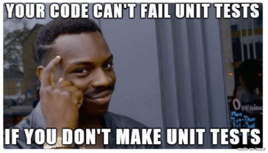
```
const Grid<string> TEST_BOARD;

void checkBadUserLoc () {
    // (-1, -1) is a bad location
    Vector<Point> possibleMoves = getPossibleMoves
        (TEST_BOARD, -1, -1);

    // There are no moves from invalid location
    assert(possibleMoves.size() == 0);
}
```

Testing takeaways

- Think about tests early, and think about them often!
- This class does not heavily focus on unit tests in assignments, but software engineering in general does.
- Unit tests are a lot of work to write! But they're valuable when code is used in production and frequently updated.



Unit what?

Meme taken from me.me

Thank you!

- Any questions? Email me at shreya@cs.stanford.edu or come to my office hours today (Tuesday) from 1:30-3:30 PM in Gates B02
- Assignment 1 (Life) due Thursday
- Today is last day of LaIR before assignment is due
- No class tomorrow – have a great 4th of July!