CSCI 262
Data Structures

6 – Stacks and Queues

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Overview

- Previously: linked lists
  - Easy addition/remove at ends
  - O(1) – constant time – operations:
    - Add to front
    - Add to end
    - Remove from front
- This time: stacks & queues
  - *Only* permit operations at ends
  - Easily implemented with linked lists
  - Despite simplicity, lots of applications

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Last in, first out:

STACKS

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"Last in, first out"

Stacks are a **LIFO** (Last in, first out) structure.

Think of pancakes:

This pancake was put on top last.

Which one would you eat first?
Which would you eat second?

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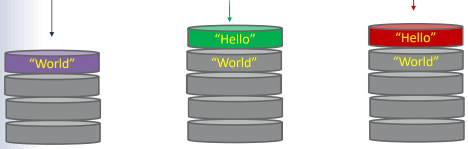
Three Operations

top: Look at the top item on the stack.

push: Add an item to the top of the stack.

pop: Remove the top item from the stack.



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A Simple Stack Class

```
class stack {
public:
        char top();
        void push(char c);
        void pop();
        size_t size();
        bool is_empty();

private:
        // private stuff
};
```

These operations are sometimes combined, e.g., pop() may return the top value on the stack as well as removing it from the stack.

To think about:
Note that both push and pop operate on the *top* of the stack; if you used a (singly) linked list implementation, which end of the list would hold the top element?
What if you used a vector instead?

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Using Stacks

What does this code do?

```
stack letters;
string text = "Data structures";
for (int j = 0; j < text.length(); j++) {
    letters.push(text[j]);
}

while (!letters.is_empty()) {
    cout << letters.top();
    letters.pop();
}
```


Applications

- Syntax analysis
  - Are parentheses, brackets, etc. balanced?
  - Nested structures (e.g., functions & variable scopes)
- Traversing/searching branching structures
  - Trees
  - Mazes
- Programming languages/processors
  - Forth, Postscript
  - Stack machines (e.g., Java virtual machine)

Balancing Game

Rules:

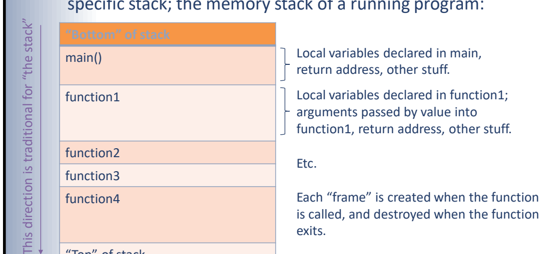
- To start, make an empty stack.
- If you see a (, {, or [, push it onto the stack
- If you see a), }, or], try to pop the *matching* delimiter from the stack, but:
  - If the stack is empty, yell "UNDERFLOW!"
  - If wrong character is at the top, yell "SYNTAX ERROR!"
- When the game ends, if your stack is empty, yell "I WIN!" else yell "SYNTAX ERROR!"

Balancing Game Inputs

- (easy)
- [[x];
- {um}]-
- {(a)|(b)}(c)
- ((x + y)*(m[a)]{z})
- ((x + y)*(m[a]){z})

"The Stack"

When we talk about "the stack", we usually mean a very specific stack; the memory stack of a running program:



STL Stack

#include <stack>

template <class ValueType> class stack

Operations:

push(ValueType v)	// **push** value onto top of stack
pop()	// **pop** (remove) top value
top()	// return **top** value
size()	// return number of elements
empty()	// true if no elements

First in, first out:

QUEUES

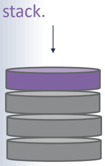
"First in, first out"

Queues are a **FIFO** (first in, first out) structure.
Think of a line of people waiting their turn:

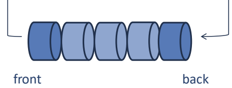
If people are polite, the first in line is done first.

Queue vs. Stack

Stack. All interactions are with the *top* of the stack.

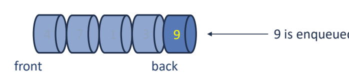


Queue: items are added to the *back* and taken from the *front*.

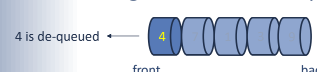


Operations

- Adding an item to a queue: *enqueue**



- Removing an item from a queue: *de-queue**



*These are the modern names. You'll find lots of implementations using "push" and "pop" instead, including the STL.

A Simple Queue Class

```
class queue {
public:
        char front();
        void enqueue(char c);
        void dequeue();
        size_t size();
        bool is_empty();

private:
        // private stuff
};
```

If you used a (singly) linked list implementation, which end of the list should hold the front element? Would a vector make a good queue implementation?

Using Queues

What does this code do?

```
queue letters;
string text = "Data structures";
for (int j = 0; j < text.length(); j++) {
    letters.enqueue(text[j]);
}

while (!letters.is_empty()) {
    cout << letters.front();
    letters.dequeue();
}
```

Uses for Queues

Anywhere you need to keep things in order, particularly by time of arrival:

- Buffering character input
- Print jobs
- Process scheduling
- I/O request scheduling
- Web page request servicing
- Event handling (GUI, simulations, etc.)

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STL Queue

#include <queue>

template <class ValueType> class queue

Operations:

```
push(ValueType v)    // enqueue (add value to back)
pop()                // dequeue (remove front value)
front()              // return front value
back()               // return back value
size()               // return number of elements
empty()              // true if no elements
```

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Stack/queue applications

GRAPH SEARCH

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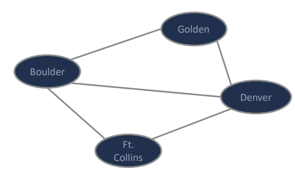
Graphs

In computer science (and math) *graphs* model relationships between things.

E.g., what cities are connected to each by a highway?



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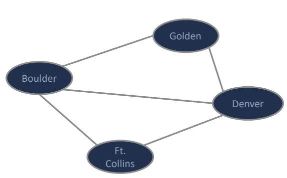
Finding Your Way

If I want to get from Ft. Collins to Golden, how can I find:

- Some path
- The shortest path
- The path going through the fewest other cities
- …



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Graph Algorithms

- Many powerful algorithms on graphs
  - Answer the above questions and more
  - Study these in CSCI 406 – Algorithms
- Two key algorithms for graph search:
  - Depth-first search – can use recursion OR **stacks**
  - Breadth-first search – easiest to use **queues**

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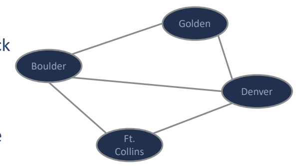
Depth-First Search (DFS)

- Push Ft. Collins onto the stack
- While the stack is not empty:
  - Pop a city from the stack
  - If the city is Golden, done!
  - Otherwise, push all adjacent cities onto the stack

(Illustration on board)



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Breadth-First Search (BFS)

- Same as DFS, but using a queue
- DFS goes as far as it can go until getting stuck, then backs up to most recent "intersection"
  - Lots of applications, mostly related to other graph algorithms/applications
- BFS goes to all nearest cities first, then the next nearest cities, etc.
  - Great for finding fewest hops
  - With some tweaks, can find *shortest* path

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Up Next

- Today
  - Read Sections 12.1 – 12.3, 14.3
  - Lab 3 due
- Wednesday, January 30
  - Analysis of algorithms & Big O
  - Selection sort
- Friday, February 1
  - Lab 4 – TBD
  - Project 2 – Mazes assigned (graph search!)
  - APT 2 due

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