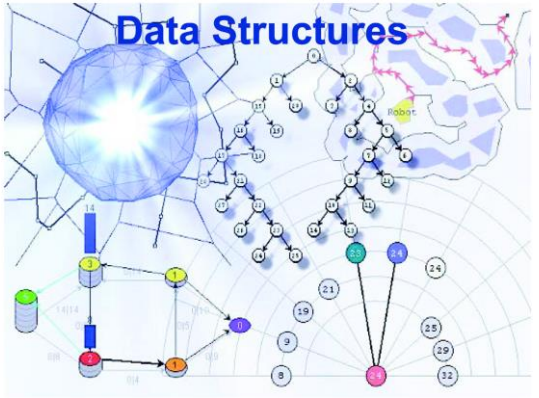
BBM 201
DATA STRUCTURES

Lecture 1:
Basic concepts for data structures



About the course

- This course will help students understand the **basic data structures** such as matrices, stacks, queues, linked lists, etc.

- **BBM 203 Programming Laboratory:** The students will gain hand-on experience via a set of programming assignments supplied as complementary.

- **Requirements**: You must know basic programming (i.e. BBM101).

References

- Data Structures and Algorithm Analysis in C++. 4th Edition. Mark Allen Weiss, Pearson, 2014

- Fundamentals of Data Structures in C++. Ellis Horowitz, Sartaj Sahni, and Susan Anderson-Freed, Computer Science Press, 1995.

- Data Structures Notes, Mustafa Ege.

Communication

- The course web page will be updated regularly throughout the semester with lecture notes, programming assignments, announcements and important deadlines.

  http://web.cs.hacettepe.edu.tr/~bbm201

Getting Help

- **Office hours**

  See the web page for details

- **BBM 203 Programming Laboratory**

  Course related recitations, practice with example codes, etc.

- **Communication**

  Announcements and course related discussions through piazza

  BBM 201: https://piazza.com/hacettepe.edu.tr/fall2022/bbm201

  BBM 203: https://piazza.com/hacettepe.edu.tr/fall2022/bbm203

Course Overview

BBM201 Schedule (Tentative)

Week	Topic
1	Orientation and Motivation
2	Basic concepts for data structures, performance analysis, space and time complexity
3	Representation of multidimensional arrays, matrix representation
4	Record/struct, list
5	Linked list
6	**Midterm Exam I**
7	Stack, Queue
8	Trees, Binary Trees, Binary Search Trees
9	Balanced Trees: AVL , LLRBT
10	Hash Tables
11	**Midterm Exam II**
12	Graph representation
13	String, Trie
14	Priority Queues (Heaps)
	Final Exam

BBM201 Grading

- **2 Midterm Exams (2 x 25%)**
- **Final exam (50%)**

BBM 203 Programming Laboratory I

- **Programming assignments (PAs)**
  - Four assignments throughout the semester.
  - Each assignment has a well-defined goal such as solving a specific problem.
  - You **must work alone** on all assignments stated unless otherwise.

BBM 203 Programming Laboratory I

BBM203 Schedule (Tentative)

Week	Lab	Assignment	Quiz
1	Tutorial: Java to C++ Transition		
2	Tutorial: Java to C++ Transition		
3	Tutorial: Java to C++ Transition	PA1: Array & Matrices	
4	Tutorial: Java to C++ Transition		
5			Q1
6	Office hour, Recitation	PA2: Linked list	
7	Office hour, Recitation		
8		PA3: Stack & Queue	Q2
9	Office hour, Recitation		
10		PA4: Trees	Q3
11	Office hour, Recitation		
12	Office hour, Recitation		
13			Q4
14	Office hour, Recitation		

BBM203 Lab Grading

- **4 Programming Assignments (4 x 20%)**

- **4 Quizes (4 x 5%)**

The joy of learning

Policies

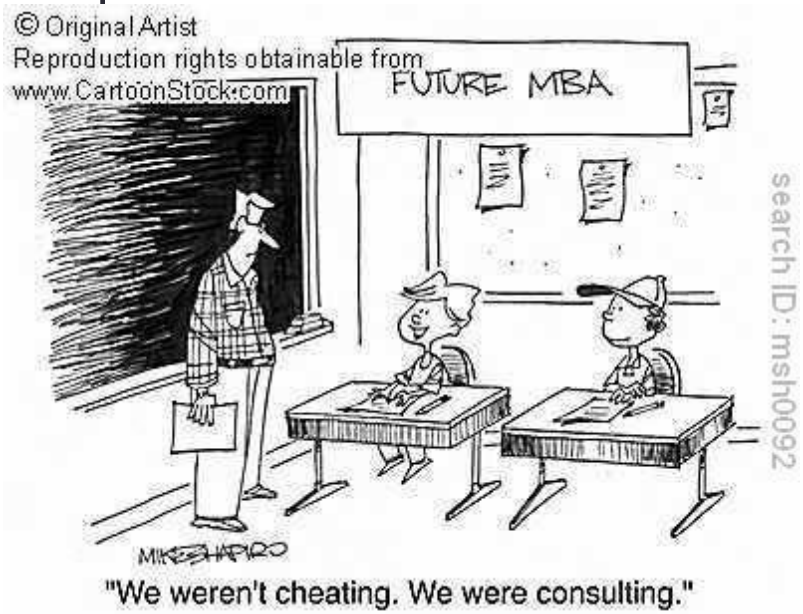
- **Work groups**
  - You must work alone on all assignments stated unless otherwise

- **Submission**
  - Assignments due at 23:59 (no extensions!)
  - Electronic submissions (no exceptions!)

- **Lateness penalties**
  - No late submission is accepted

Cheating

- **What is cheating?**
  - Sharing code: by copying, retyping, looking at, or supplying a file
  - Coaching: helping your friend to write a programming assignment, line by line
  - Copying code from previous course or from elsewhere on WWW



- **What is NOT cheating?**
  - Explaining how to use systems or tools
  - Helping others with high-level design issues

Cheating

- **Penalty for cheating:**
  - Suspension from school for 6 months (minimum)

YÜKSEKÖĞRETİM KURULU

- **Detection of cheating:**
  - We do check: Our tools for doing this are much better than most cheaters think!

BASIC CONCEPTS
FOR DATA STRUCTURES

Digital Data

Movies

Music

Photos

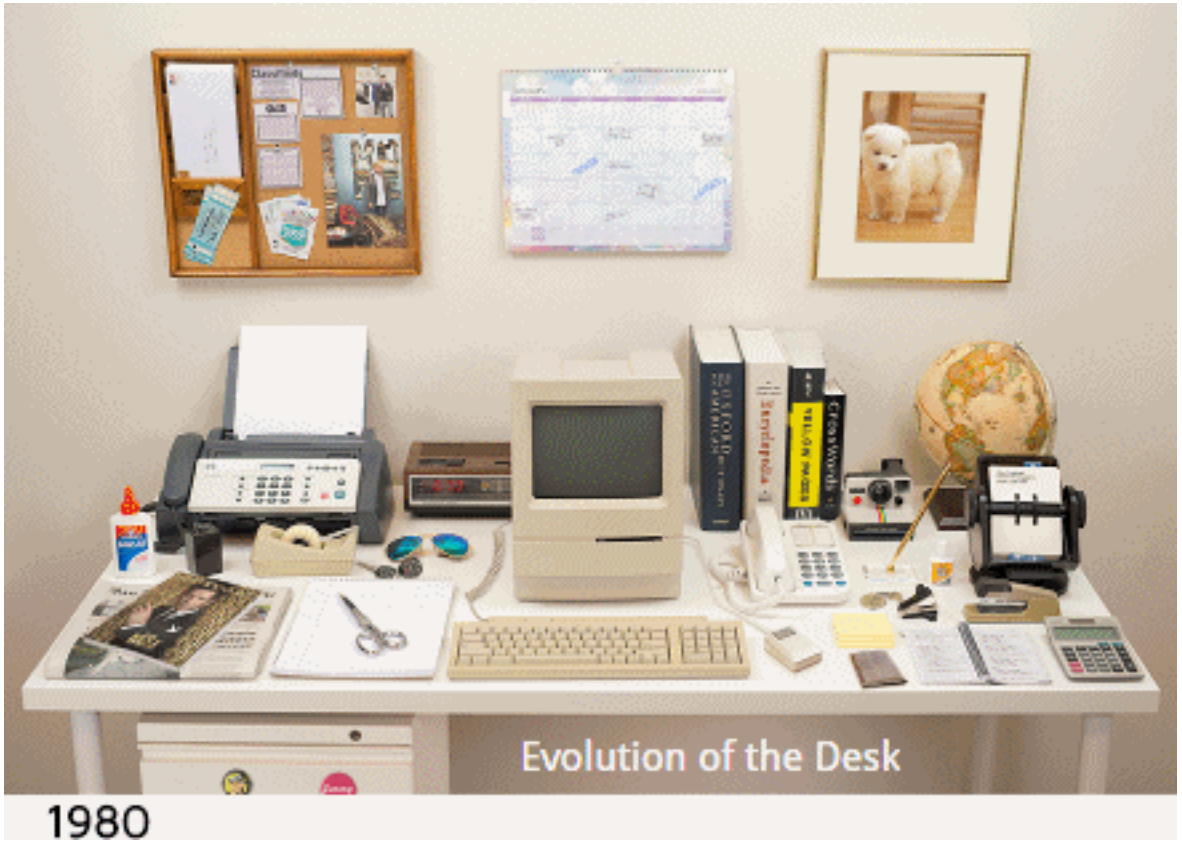
Protein Shapes

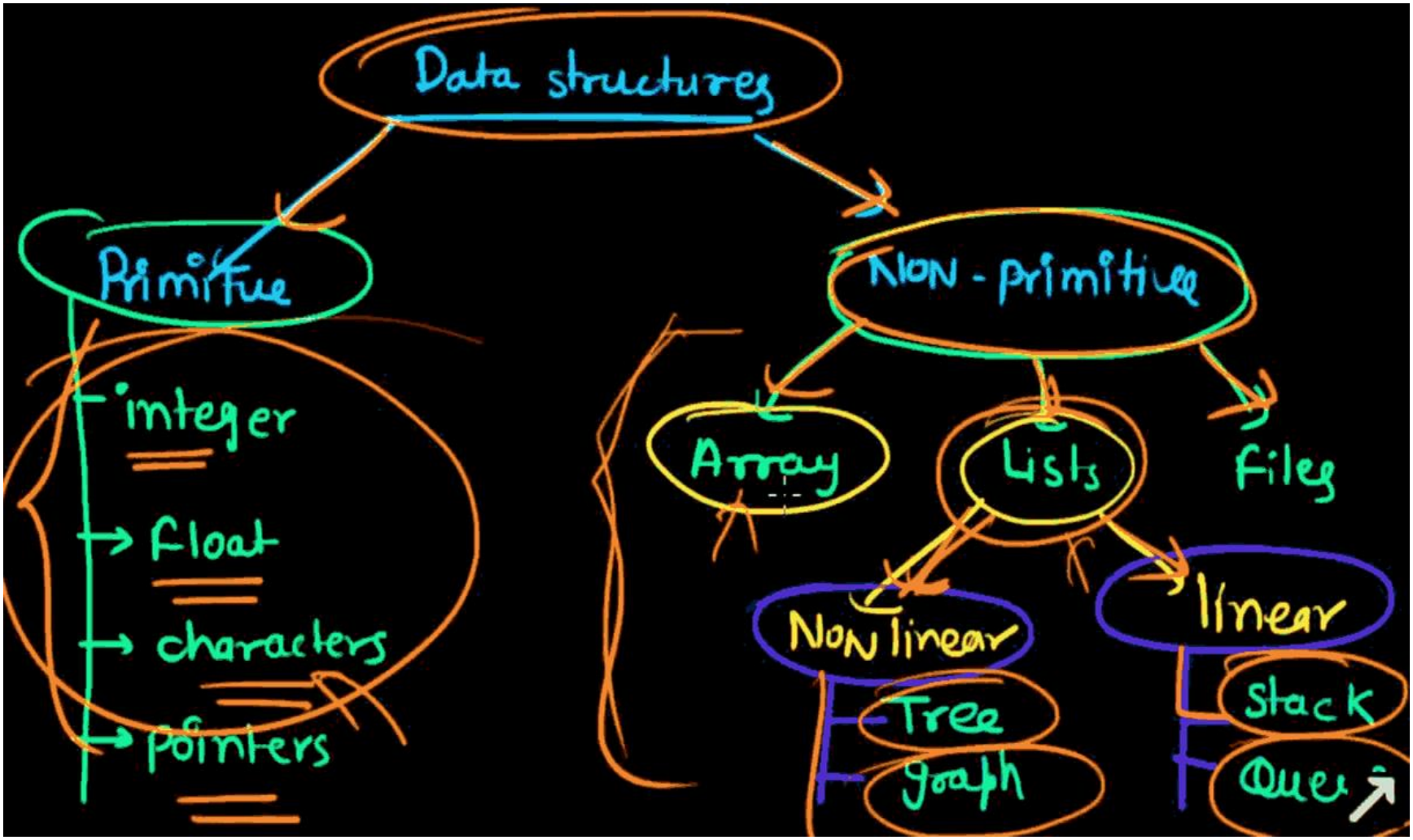
DNA

```
gatcttttta tttaaacgat ctctttatta gatctcttat taggatcatg atcctctgtg
gataagtgat tattcacatg gcagatcata taattaagga ggatcgtttg ttgtgagtga
ccggtgatcg tattgcgtat aagctgggat ctaaatggca tgttatgcac agtcactcgg
cagaatcaag gttgttatgt ggatatctac tggttttacc ctgcttttaa gcatagttat
acacattcgt tcgcgcgatc tttgagctaa ttagagtaaa ttaatccaat ctttgaccca
```

Maps

00|0|0|00|0|0|0|0|0|00|00|00|0|0|00000|00|00|0|00....


Evolution of the Desk
1980


Data structures
Primitive
integer
float
characters
pointers
Non-primitive
Array
Lists
Files
Non linear
Tree
Graph
linear
Stack
Queue


1
2
3
4
5
6
7

Digital Data Must Be ...

- Encoded (e.g. 01001001 <-> )

- Arranged
  - Stored in an orderly way in memory / disk

- Accessed
  - Insert new data
  - Remove old data
  - Find data matching some condition

} The focus of this class

- Processed
  - Algorithms: shortest path, minimum cut, FFT, ...

Data Structure vs Data StructurING

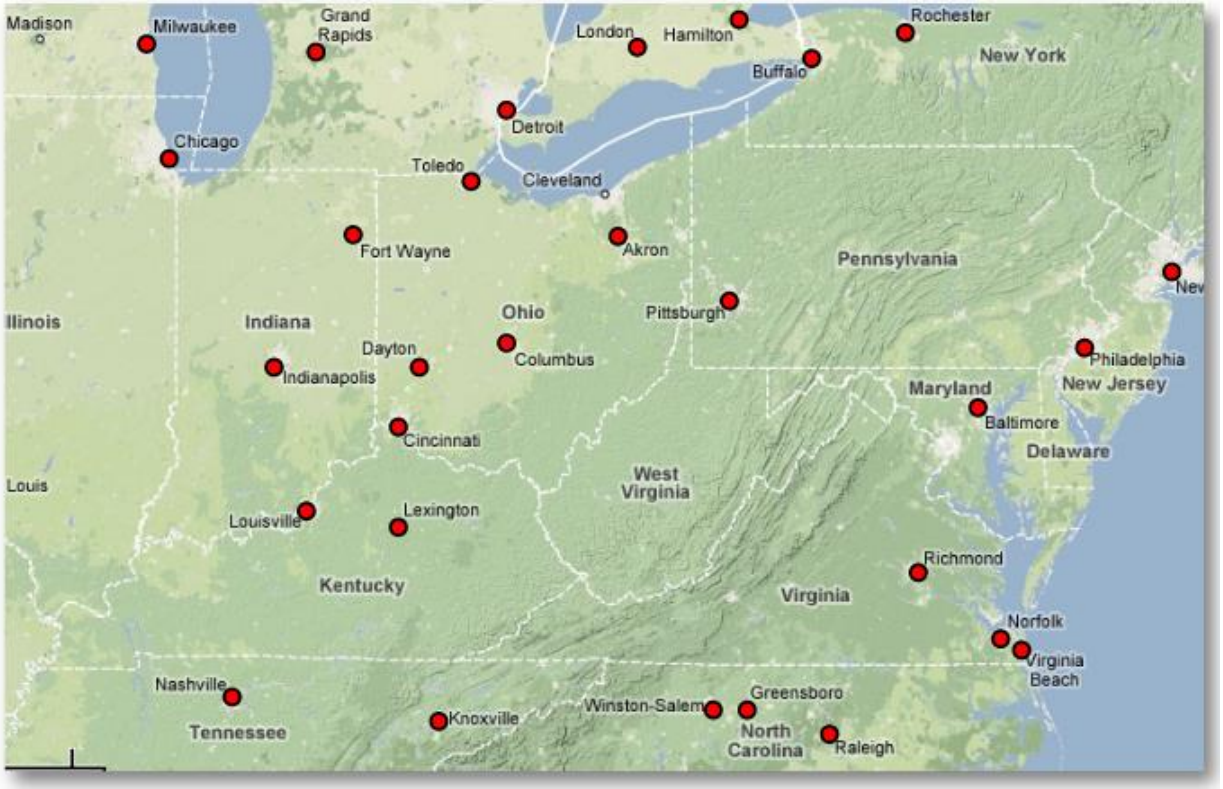
How do we organize information so that we can find, update, add, and delete portions of it efficiently?

Data Structure Example Applications

- How does Google quickly find web pages that contain a search term?
- What's the fastest way to broadcast a message to a network of computers?
- How can a subsequence of DNA be quickly found within the genome?
- How does your operating system track which memory (disk or RAM) is free?
- In the game Half-Life, how can the computer determine which parts of the scene are visible?

Suppose You're Google Maps…

- You want to store data about cities (location, elevation, population)…



What kind of operations should your data structure(s) support?

Operations to support the following scenario…

Finding addresses on map?

- *Lookup city by name...*

Mobile user?

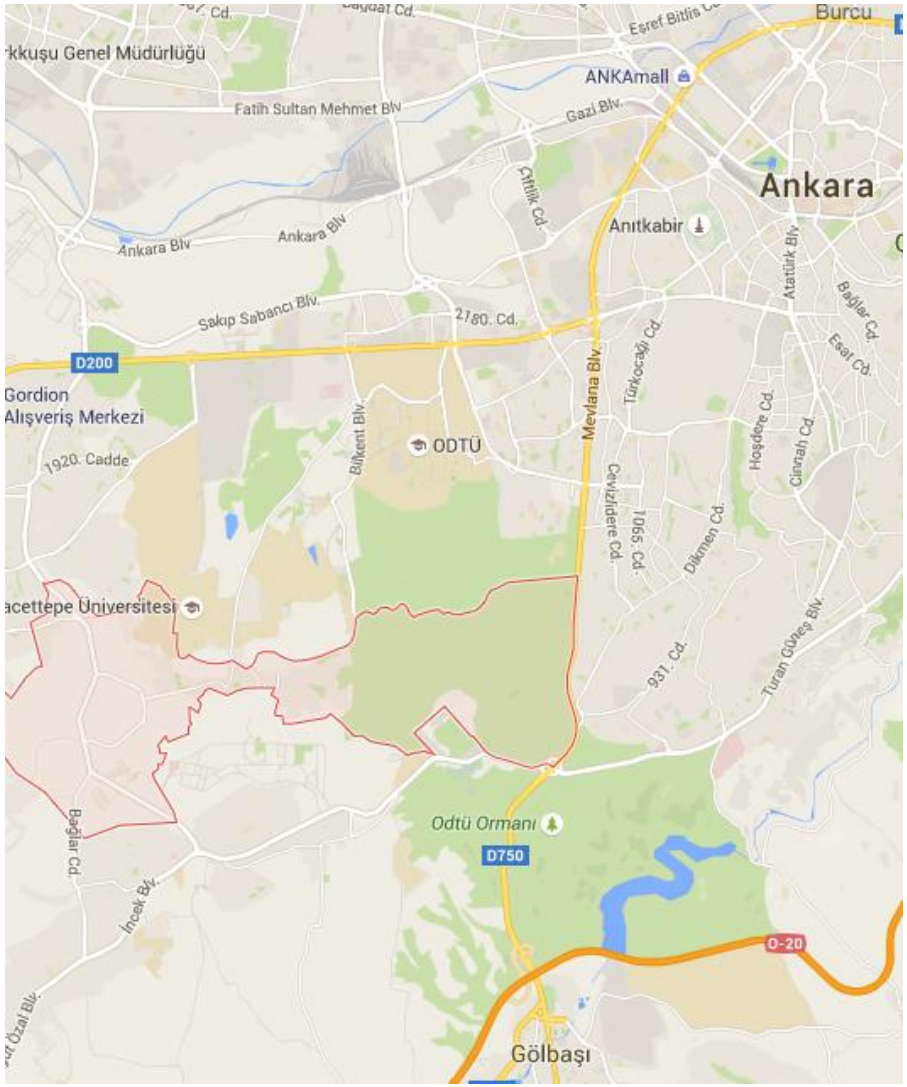
- *Find nearest point to me...*

Car GPS system?

- *Calculate shortest-path between cities…*
- *Show cities within a given window…*

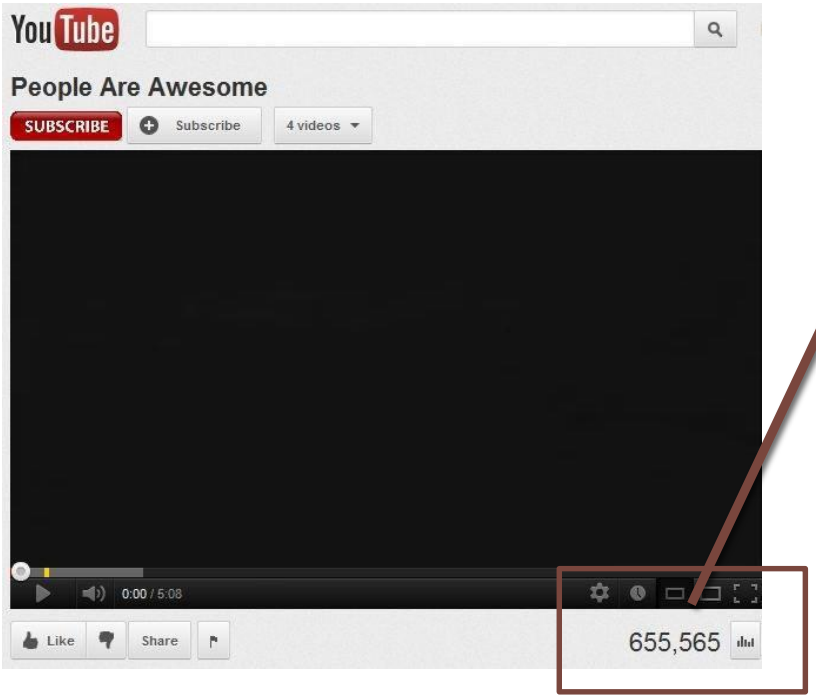
Political revolution?

- *Insert, delete, rename cities*



How will you count user views on YouTube?

- Lets write a userViewCount() function




```
int userViewCount (int current_count)
{
        int new_count;
        new_count =current_count + 1;
        return new_count;
}
```

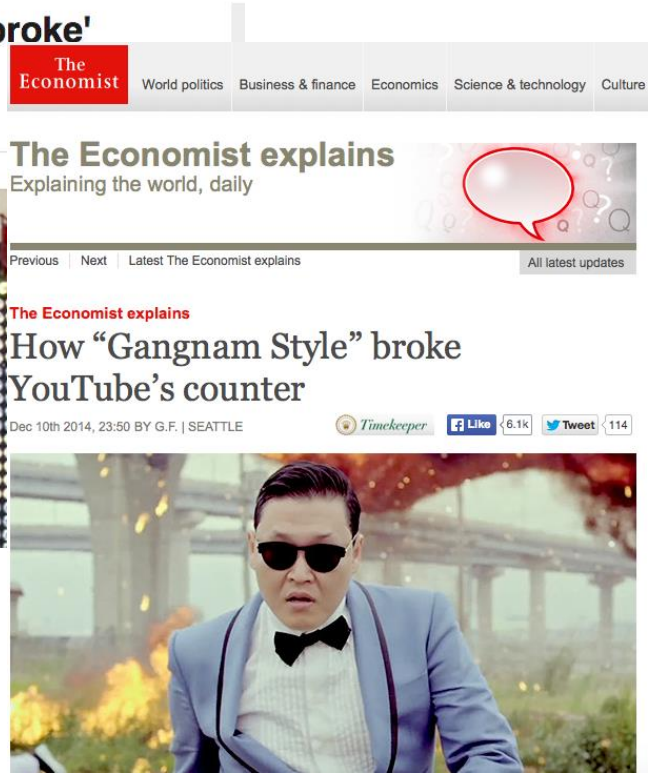
Will this implementation work all the time?

How will you count user views on YouTube?

%99.9 times yes.

How will you count user views on YouTube?

http://www.bbc.com/news/world-asia-30288542



http://www.economist.com/blogs/economist-explains/2014/12/economist-explains-6

YouTube's counter previously used a 32-bit integer

YouTube said the video - its most watched ever - has been viewed more than 2,147,483,647 times.

It has now changed the maximum view limit to 9,223,372,036,854,775,808, or more than nine quintillion.

How bad can it be?

- June 4, 1996
- Ariane 5 rocket launched by the European Space Agency
- After a decade of development costing $7 Billion

(~42 Billion in Turkish Liras, just for comparison Istanbul's third bridge cost estimates are 4.5 Billion TL)

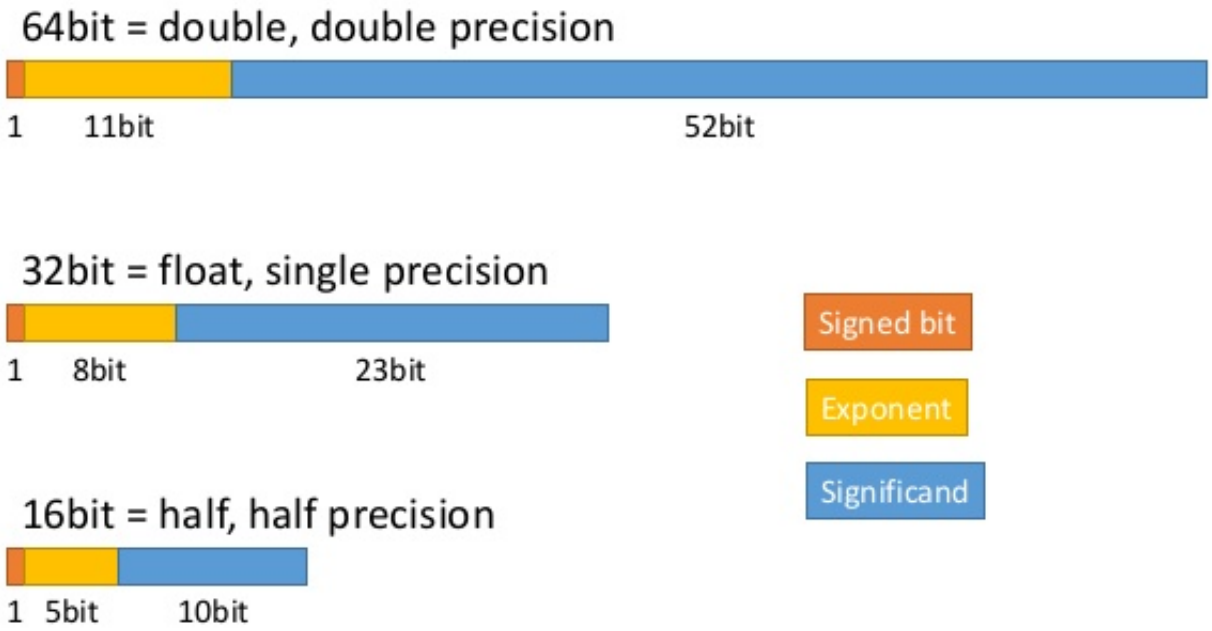
- Exploded just 40 seconds after its lift-off
- The destroyed rocket and its cargo were valued at $500 million
- Reason?

How bad can it be?

- Reason?
- Inertial reference system error: specifically a 64 bit floating point number relating to the horizontal velocity of the rocket with respect to the platform was converted to a 16 bit signed integer.
- The number was larger than 32,767, the largest integer storable in a 16 bit signed integer, and thus the conversion failed.
- $500 Million rocket/cargo
- Time and effort

Floating Point Representation

Format of Floating points IEEE754



Floating Point Representation

Nvidia Tesla Workstation GPU Performance Comparison			
	P100	**M40**	**K40**
Architecture	Pascal	Maxwell	Kepler
Double Precision (FP64)	5.3 Tflop/s	0.2 Tflop/s	1.4 Tflop/s
Single Precision (FP32)	10.6 Tflop/s	7 Tflop/s	4.3 Tflop/s
Half Precision (FP16)	21.1 Tflop/s	N/A	N/A
Memory Bandwidth	720GB/s	288GB/s	288GB/s
Memory Size	16GB	12GB / 24GB	12GB
Release Date	2016	Nov-15	Nov-13

Goals

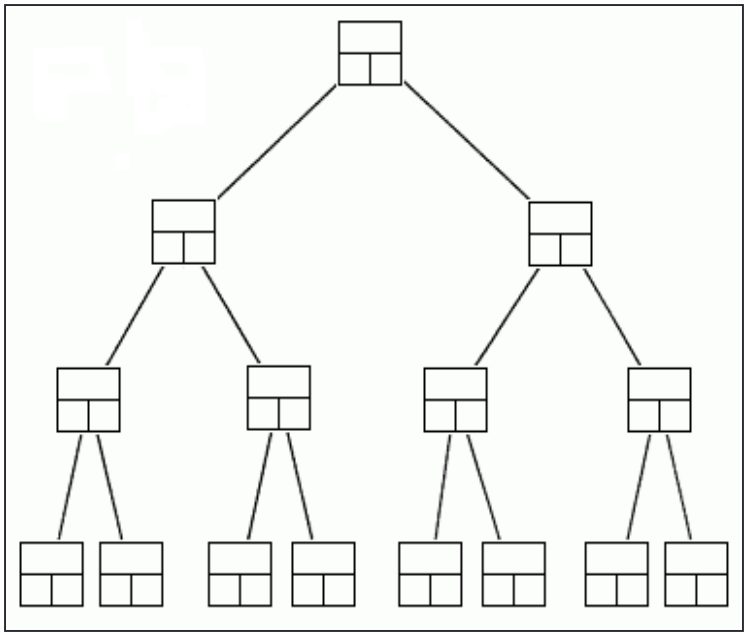
"I will, in fact, claim that the difference between a bad programmer and a good one is whether he considers his code or his data structures more important. Bad programmers worry about the code. Good programmers worry about data structures and their relationships."

Linus Torvalds, 2006

Data Structures

A data structure is a way to store and organize data in computer, so that it can be used *efficiently*.

Some of the more commonly used data structures include lists, *arrays, stacks, queues, heaps, trees, and graphs*.



Binary Tree

What are data structures?

- Data structures are software artifacts that allow data to be stored, organized and accessed.

- Ultimately data structures have two core functions: put stuff in and take stuff out.

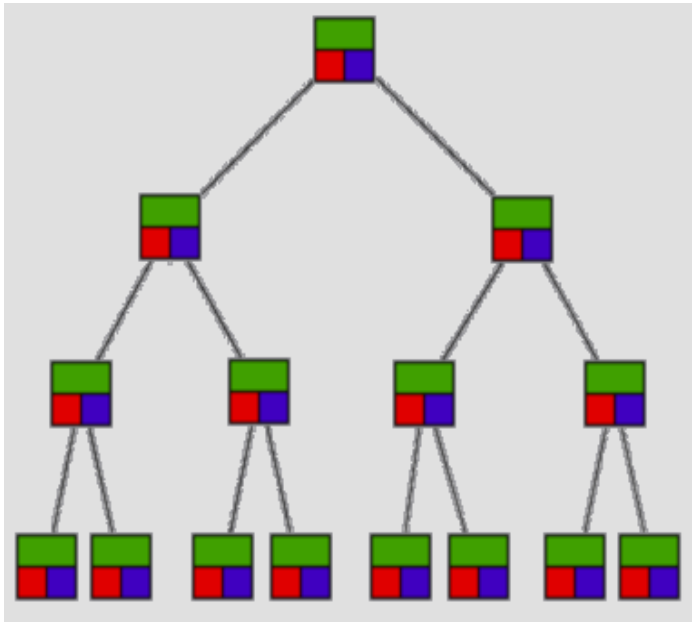
Why so many?

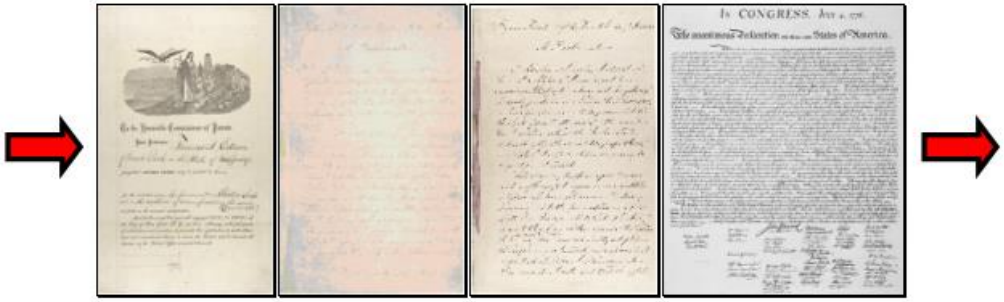
- Space efficiency
- Time efficiency:
  - Store
  - Search
  - Retrieve
  - Remove
  - Clone etc.

Choosing Data Structures

Queue vs Binary Tree

---Which one to use for what task?





Why So Many Data Structures?

- Ideal data structure:
  - “fast”, “elegant”, memory efficient
- Generates tensions:
  - time *vs.* space
  - performance *vs.* elegance
  - generality *vs.* simplicity
  - one operation’s performance *vs.* another’s

The study of data structures is the study of tradeoffs. That’s why we have so many of them!