Programming Abstractions

CS106B

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Today’s Topics

Recursion Week continues!

- Today, two applications of recursion:
  - Fractals (will help us visualize the order of operations in recursion)
  - Binary Search (one of the fundamental algorithms of CS)

Next time:

- More recursion! It’s Recursion Week!
- Like Shark Week, but more nerdy

Fractals: Boxy Snowflake Fractal

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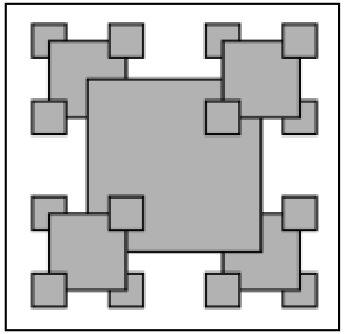
Boxy Snowflake example

Where should this line of code be inserted to produce the pattern shown on the right?

```
drawFilledBox(w, cx, cy, dim, "Gray", "Black");
```



```
const double SCALE = 0.45;

void drawFractal(GWindow& w, double cx, double cy, double dim, int order) {
   if (order == 0) return;
   drawFractal(window, cx-dim/2, cy-dim/2, SCALE*dim, order-1);
                       (A) Insert code here
   drawFractal(window, cx+dim/2, cy+dim/2, SCALE*dim, order-1);
                       (B) Insert code here
   drawFractal(w, cx-dim/2, cy+dim/2, SCALE*dim, order-1);
                       (C) Insert code here
   drawFractal(window, cx+dim/2, cy-dim/2, SCALE*dim, order-1);
                       (D) Insert code here

}
```

(E) None of the above

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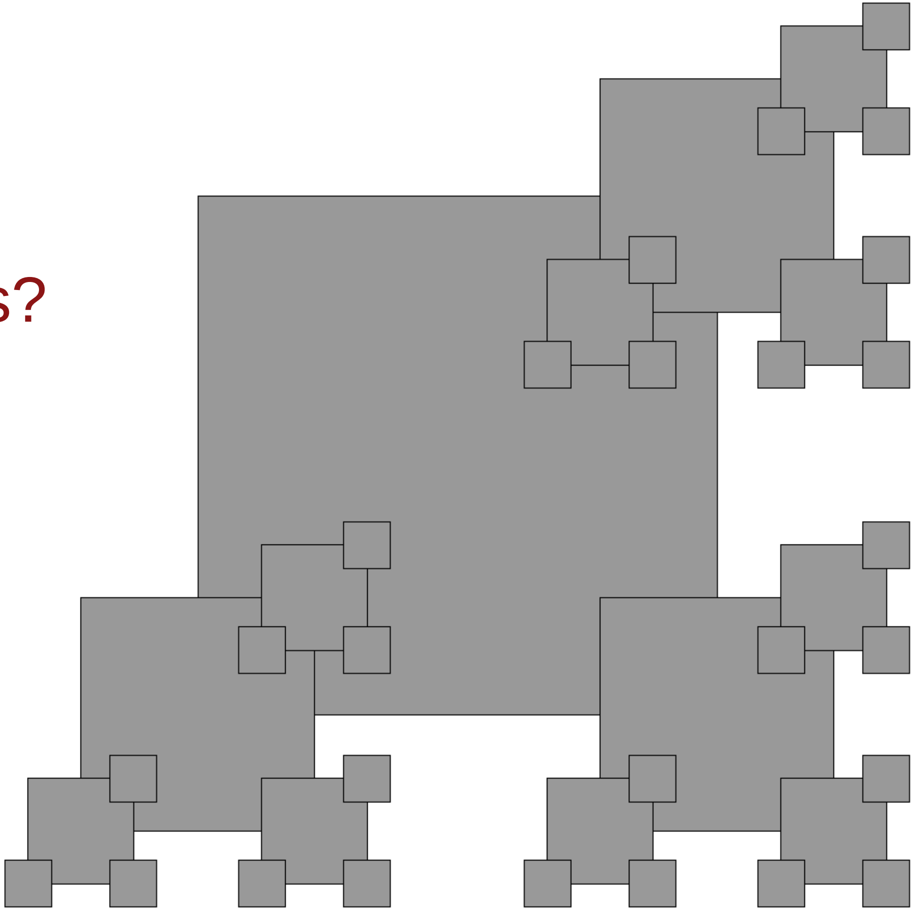
Variants:

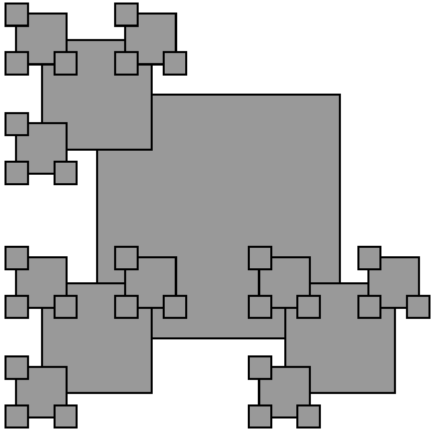
How can we code this?



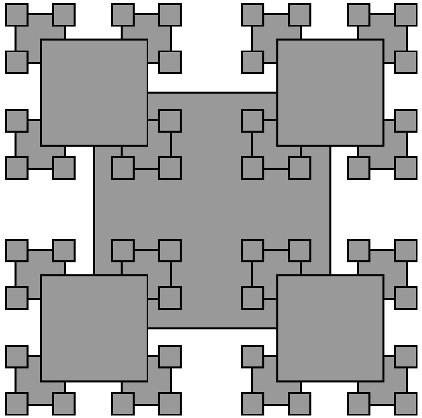
Real or Photoshop?

Can these be made by changing the order of lines and/or deleting lines in the draw() function?

(1)



(2)



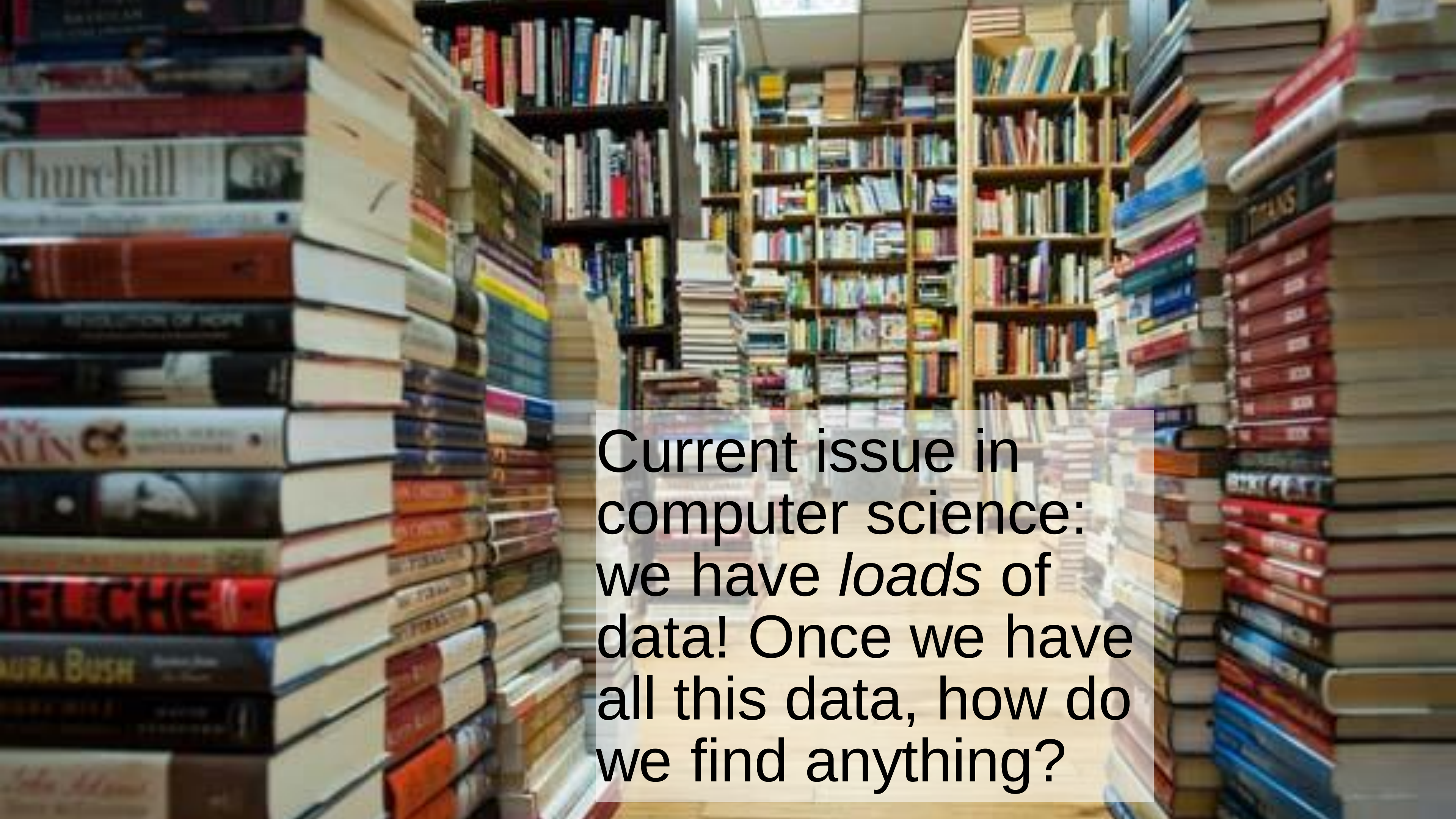
(A) Only #1 is real

(B) Only #2 is real

(C) Both are ‘shopped

(D) Both are real

Classic and important CS problem: ***searching***



Current issue in computer science: we have *loads* of data! Once we have all this data, how do we find anything?

Imagine storing **sorted** data in an array

How long does it take us to find a number we are looking for?

0	1	2	3	4	5	6	7	8	9	10
2	7	8	13	25	29	33	51	89	90	95

Imagine storing **sorted** data in an array

How long does it take us to find a number we are looking for?

0	1	2	3	4	5	6	7	8	9	10
2	7	8	13	25	29	33	51	89	90	95

If you start at the front and proceed forward, each item you examine rules out 1 item

Imagine storing **sorted** data in an array

0	1	2	3	4	5	6	7	8	9	10
2	7	8	13	25	29	33	51	89	90	95

If instead we **jump right to the middle**, one of three things can happen:

1. The middle one happens to be the number we were looking for, yay!
2. We realize we went too far
3. We realize we didn’t go far enough

Imagine storing **sorted** data in an array

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Ruling out HALF the options in one step is so much faster than only ruling out one!

Binary search

0	1	2	3	4	5	6	7	8	9	10
2	7	8	13	25	29	33	51	89	90	95

Let’s say the answer was case 3, “we didn’t go far enough”

- We ruled out the entire first half, and now only have the second half to search
- We could start at the front of the second half and proceed forward checking each item one at a time…

Binary search

0	1	2	3	4	5	6	7	8	9	10
2	7	8	13	25	29	33	51	89	90	95

Let’s say the answer was case 3, “we didn’t go far enough”

- We ruled out the entire first half, and now only have the second half to search
- We could start at the front of the second half and proceed forward checking each item one at a time… but why do that when we know we have a **better way**?

Jump right to the middle of the region to search

Binary search

0	1	2	3	4	5	6	7	8	9	10
2	7	8	13	25	29	33	51	89	90	95

Let’s say the answer was case 3, “we didn’t go far enough”

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RECURSION!!

Jump rig u of the region to search

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Designing a recursive algorithm

- Recursion is a way of taking a big problem and repeatedly breaking it into smaller and smaller pieces until it is so small that it can be so easily solved that it almost doesn't even need solving.
- There are two parts of a recursive algorithm:
  - base case: where we identify that the problem is so small that we trivially solve it and return that result
  - recursive case: where we see that the problem is still a bit too big for our taste, so we chop it into smaller bits and call *our self* (the function we are in now) on the smaller bits to find out the answer to the problem we face

Binary Search

```
bool binarySearch(const Vector<int>& data, int key){
  return binarySearch(data, key, 0, data.size() - 1);
}

bool binarySearch(const Vector<int>& data, int key, int start, int end){
    if (start > end) return false;
    int mid = (start + end) / 2;
    if (key == data[mid]) {
        return true;
    } else if (key < data[mid]) {
        return binarySearch(data, key, ______, ______);
    } else {
        return binarySearch(data, key, ______, ______);
    }
}
```