

Programming Abstractions

CS106X

Cynthia Lee

Recursion!

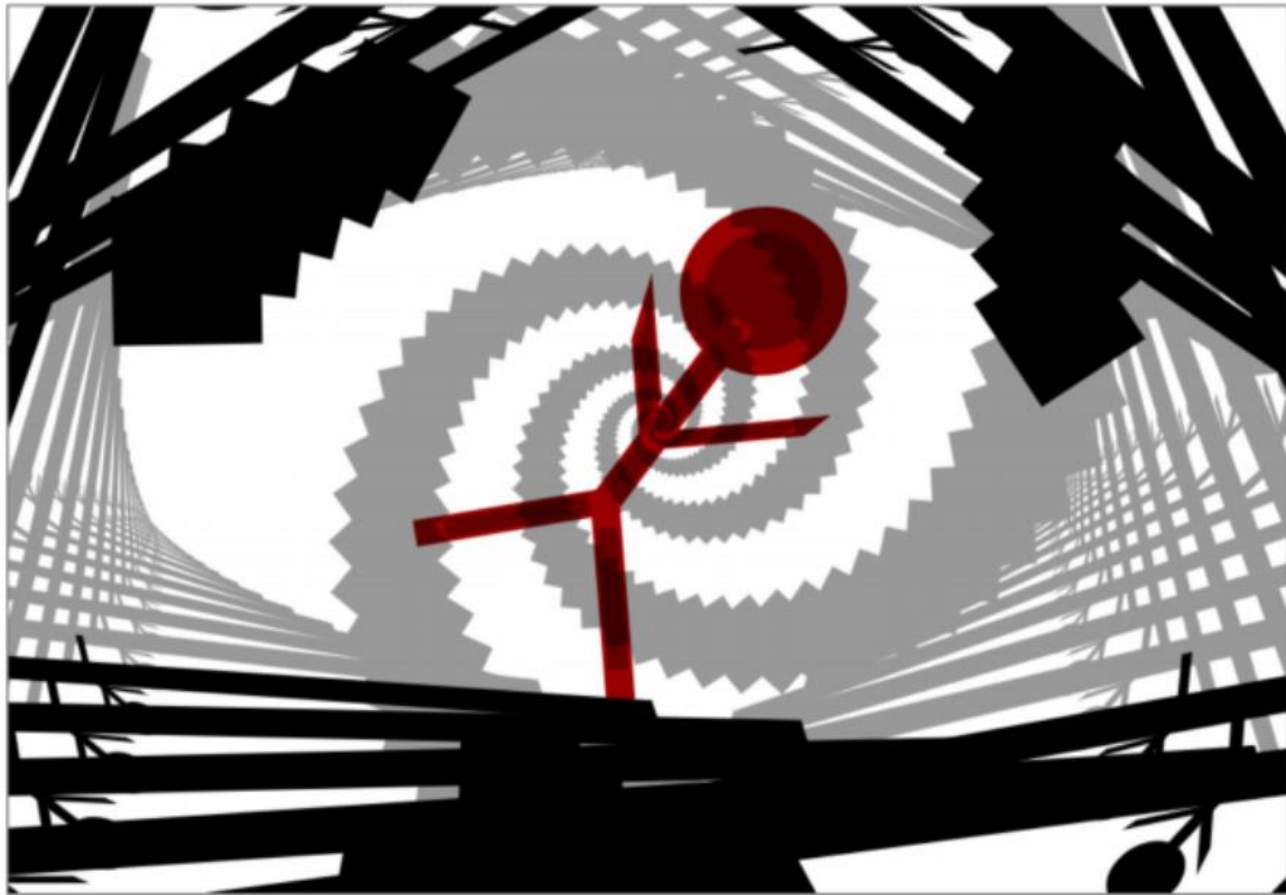
The exclamation point isn't there only because this is so exciting, it also relates to one of our recursion examples....

Announcement: Recursive art contest!

- Go to <http://recursivedrawing.com/>
- Make recursive art
 - › Win prizes!
- Come to my office hours and see my Wall of Fame of past recursive art submissions!
- Submission deadline:
 - › Wednesday of Week 4 (October 14)
- Submission procedure:
 - › Email me: cbl@stanford.edu

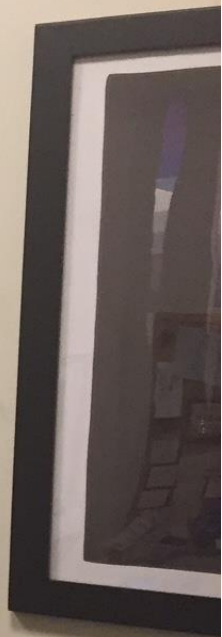
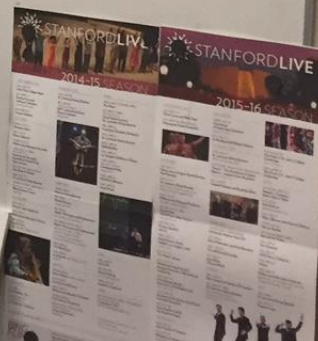
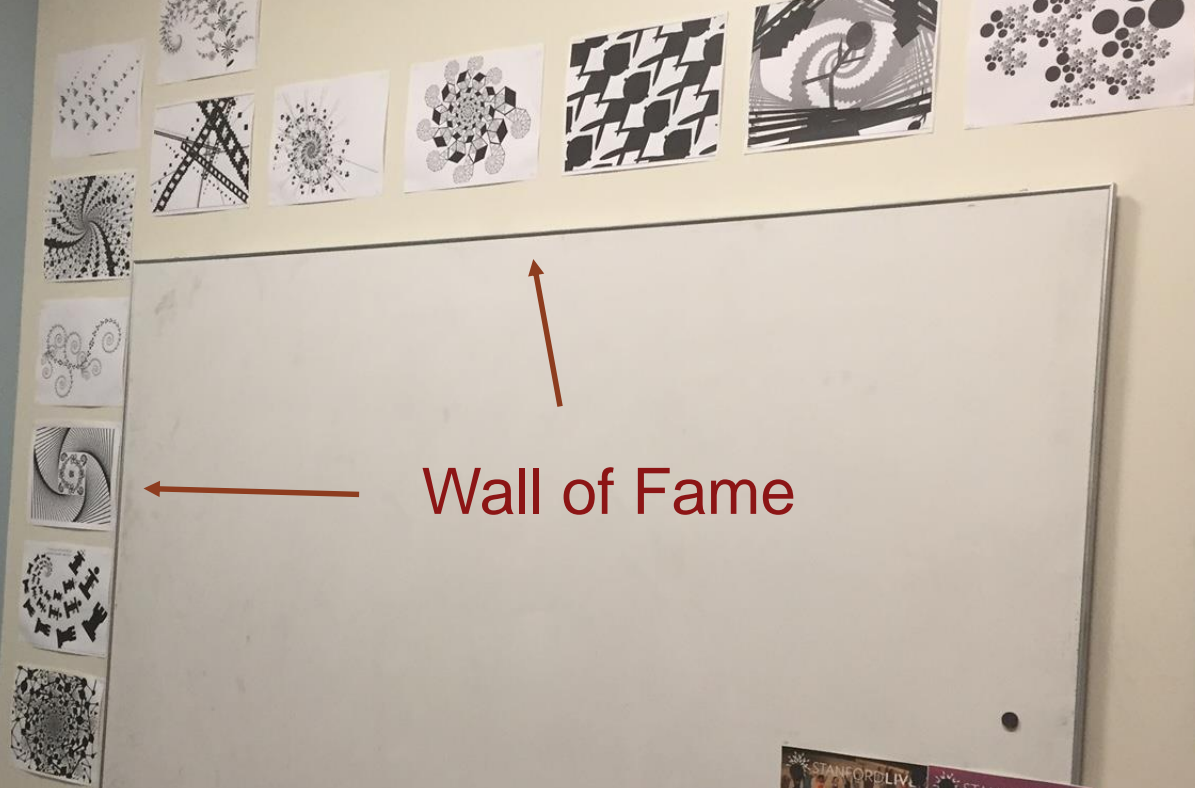
Art contest

Catherine Wong
Autumn 2013



Stanford University

Wall of Fame



Classic CS problem: searching

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 |

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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...

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...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"

- We ruled out the entire first half, and now only have the second half to search
- We could search the second half and proceed to the next step when we know we have a new range to search

Jump right to the middle of the region to search

RECURSION!!

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

To write a recursive function, we need base case(s) and recursive call(s)

What would be a good base case for our Binary Search function?

- ~~A. Only three items remain: save yourself an unnecessary function call that would trivially divide them into halves of size 1, and just check all three.~~
- ~~B. Only two items remain: so just check the two.~~
- ✓ C. Only one item remains: check it.
- ✓ D. No items remain: obviously we didn't find it.
- E. More than one

Binary Search

wrapper
function
(for users)

```
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){  
  
    //to be continued...  
}
```

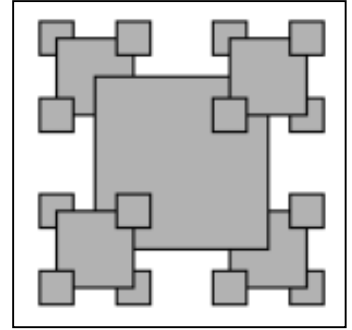
actual
recursive
function
(for our
implementation)

Fractals: Boxy Snowflake Fractal

Fractals, squee!!!

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Boxy Snowflake example



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

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

```
static const double kScale = 0.45;
```

```
static void drawFractal(GWindow& window, double cx, double cy,  
                        double dim, int order) {
```

```
    if (order >= 0) {
```

```
        drawFractal(window, cx-dim/2, cy+dim/2, kScale*dim, order-1);
```

(A) Insert code here

```
        drawFractal(window, cx+dim/2, cy-dim/2, kScale*dim, order-1);
```

(B) Insert code here

```
        drawFractal(window, cx-dim/2, cy-dim/2, kScale*dim, order-1);
```

(C) Insert code here

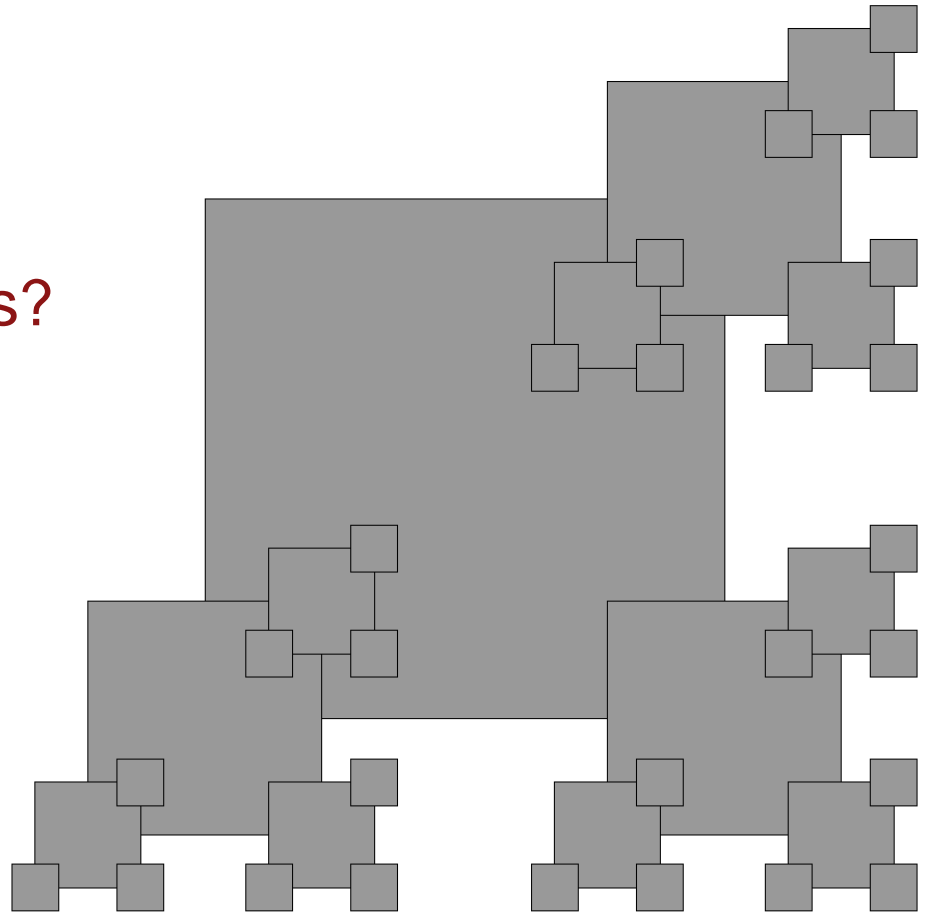
```
        drawFractal(window, cx+dim/2, cy+dim/2, kScale*dim, order-1);
```

(D) Insert code here

(E) None of the above

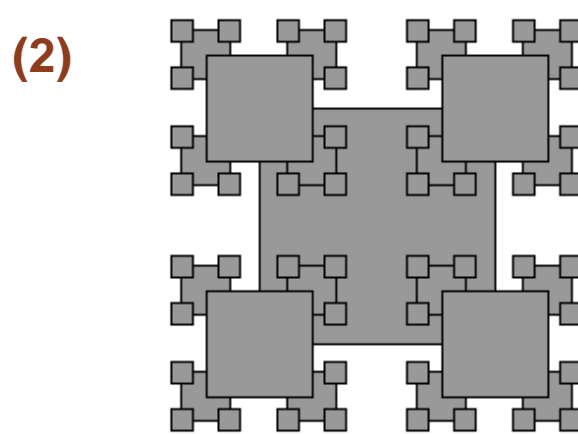
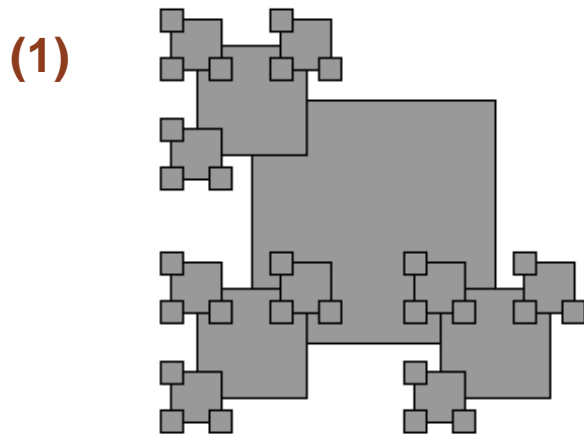
Variants:

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?



(A) Only 1 is real
(C) Both are 'shopped

(B) Only 2 is real
(D) Both are real