Programming Abstractions

CS106B

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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!

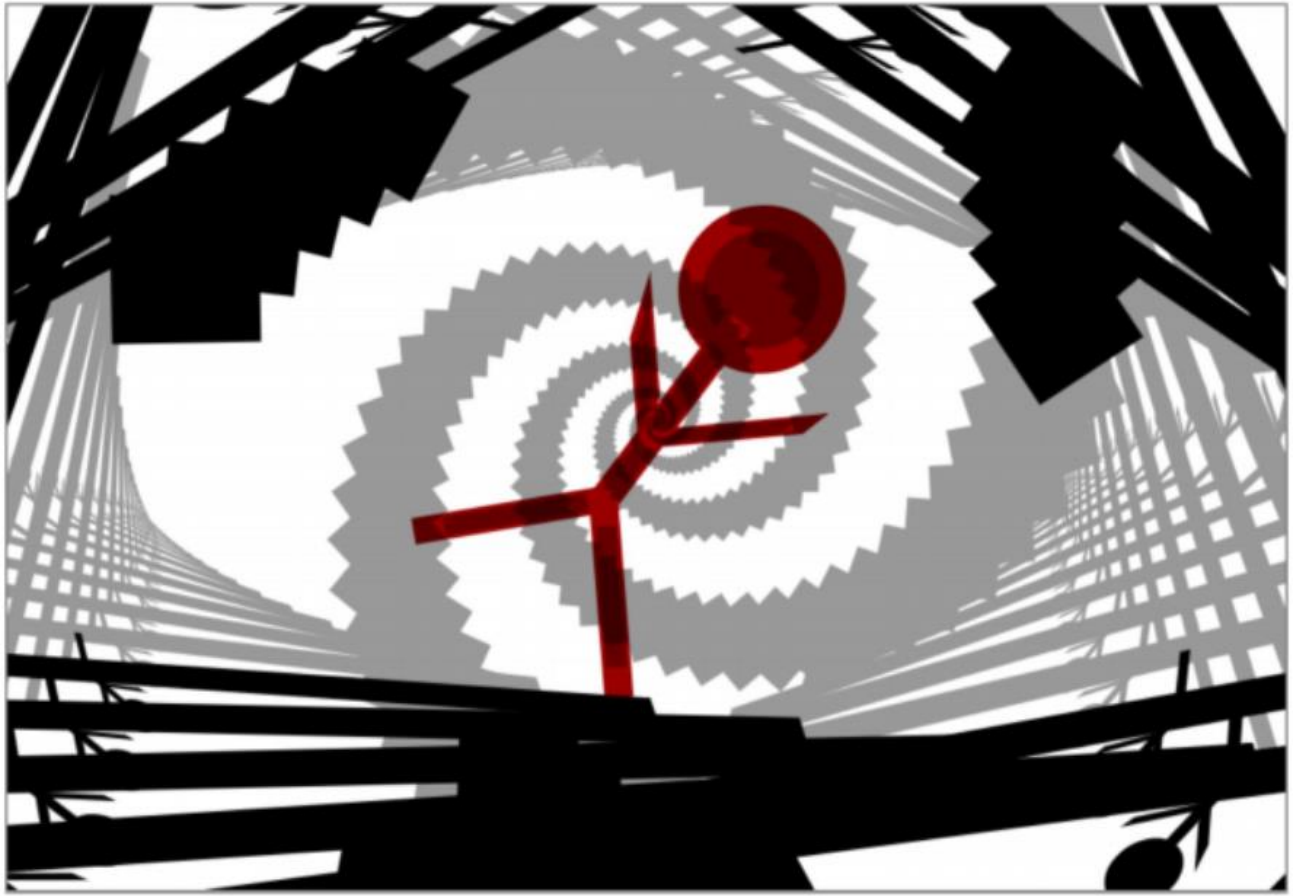
Steps to participate:

1. Go to http://recursivedrawing.com/
2. Make recursive art
3. Email me: cbl@stanford.edu
4. **Win prizes!**

Come to my office hours and see my Wall of Fame of past recursive art submissions!

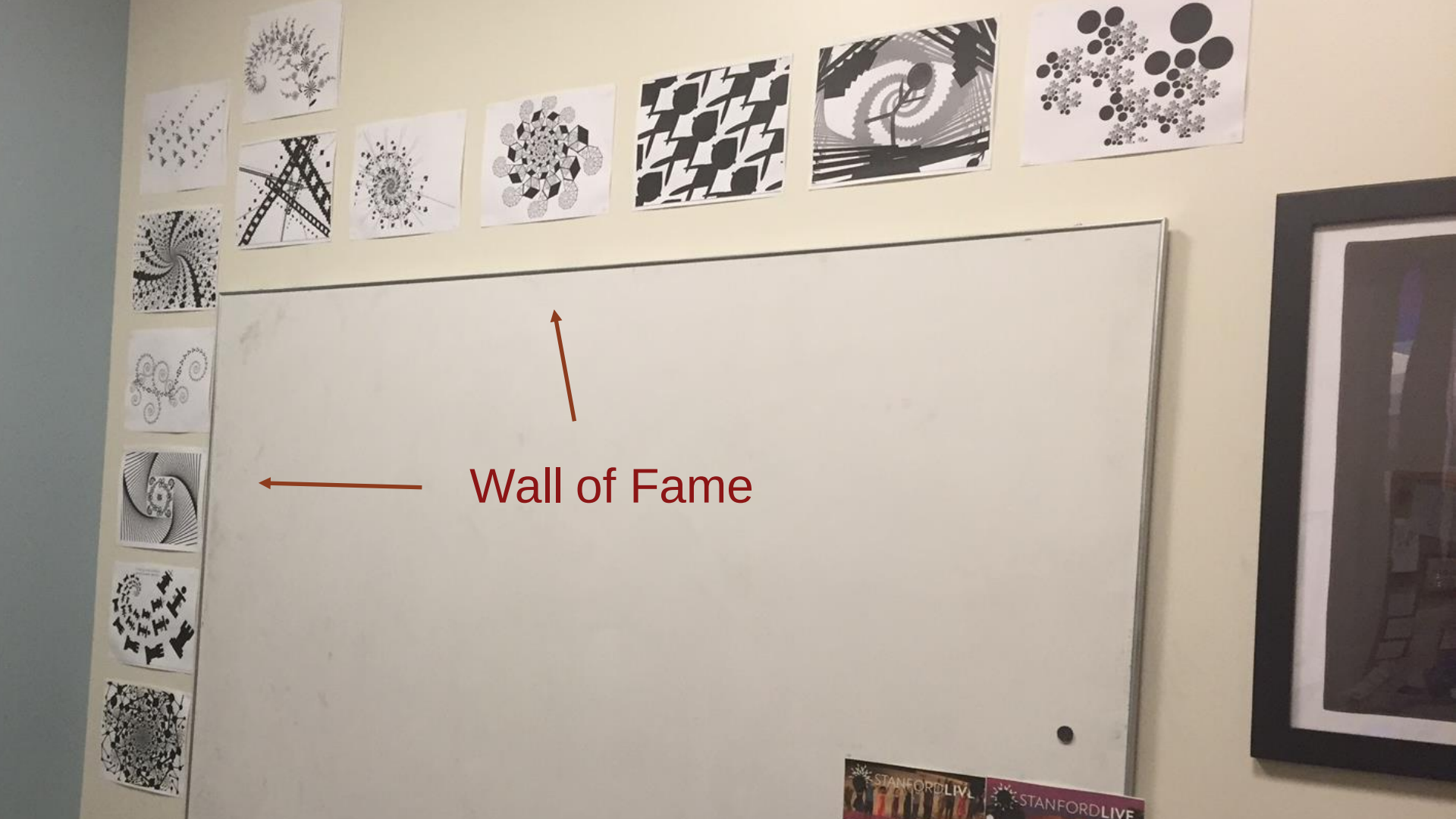
- Submission deadline:
  - Wednesday of Week 4 (April 20)

Art contest

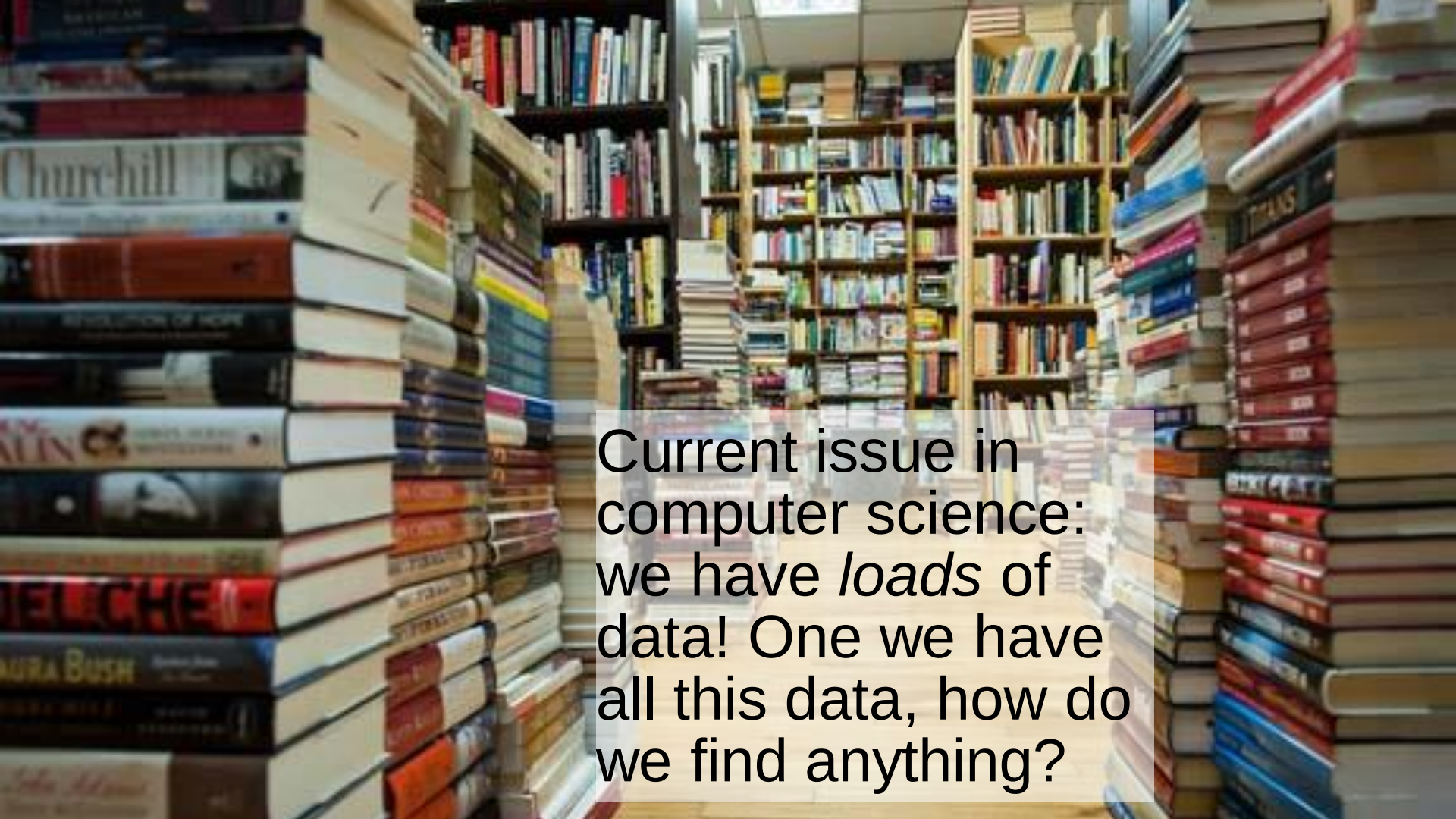


Catherine Wong

Autumn 2013


Wall of Fame

Classic and important CS problem:
searching


Current issue in computer science: we have *loads* of data! One 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

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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

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- We co second half and proceed t at when we know we have a

RECURSION!!

Jump rig of the region to search

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)

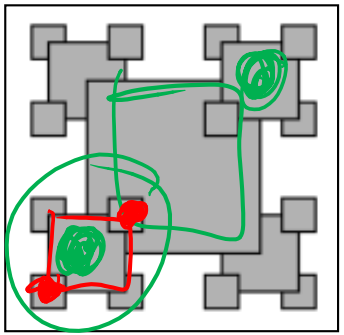
```
bool binarySearch(const Vector<int>& data, int key){
  return binarySearch(data, key, 0, data.size()-1);
}

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!!!

Boxy Snowflake example



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

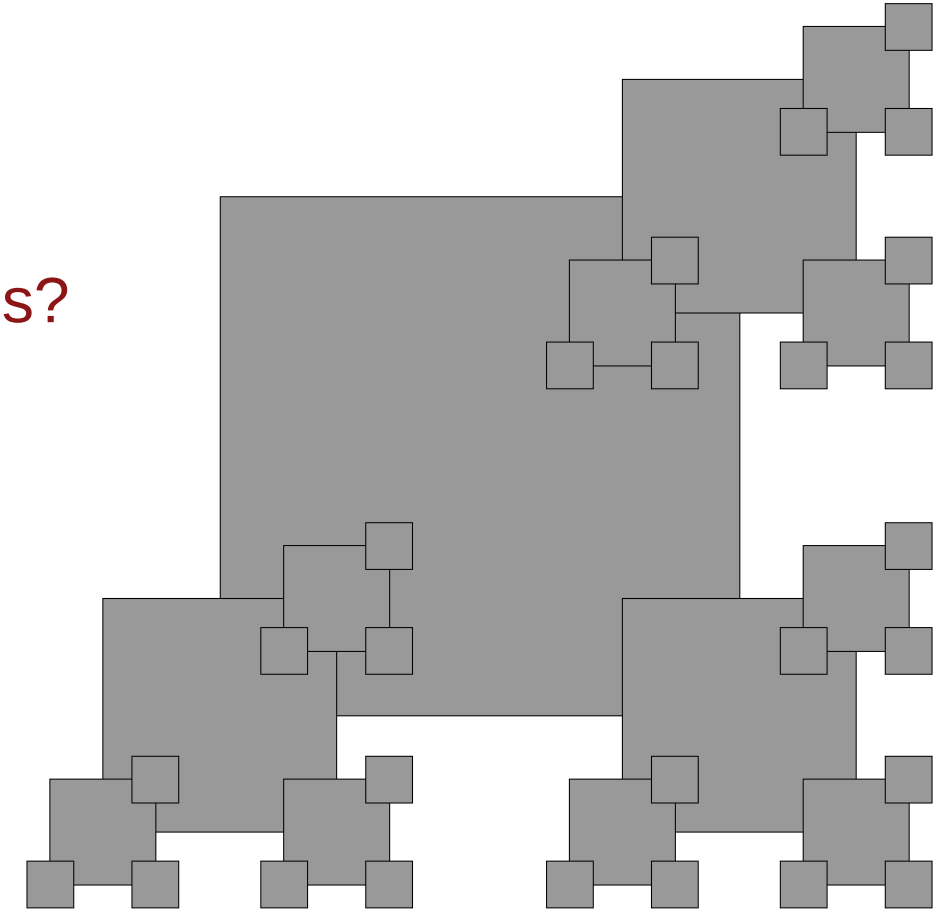
```
drawFilledBox(window, cx, cy, dim, "Gray", "Black");
```

```
static const double SCALE = 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, 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(window, 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

Variants:

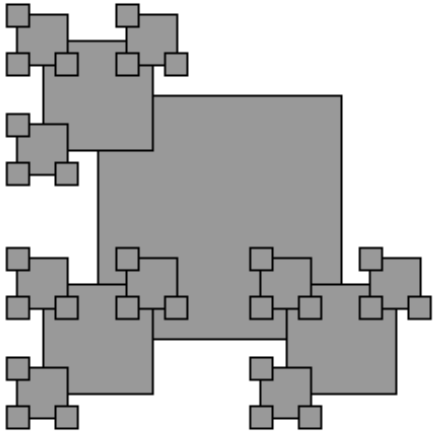
How can we code this?



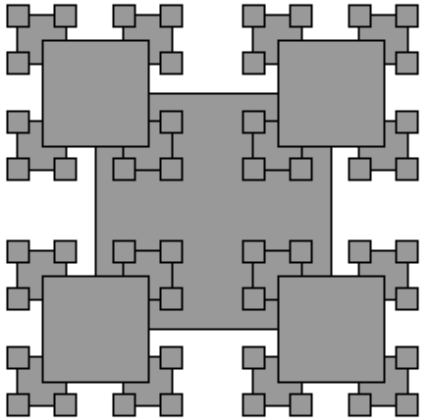
Real or Photoshop?

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