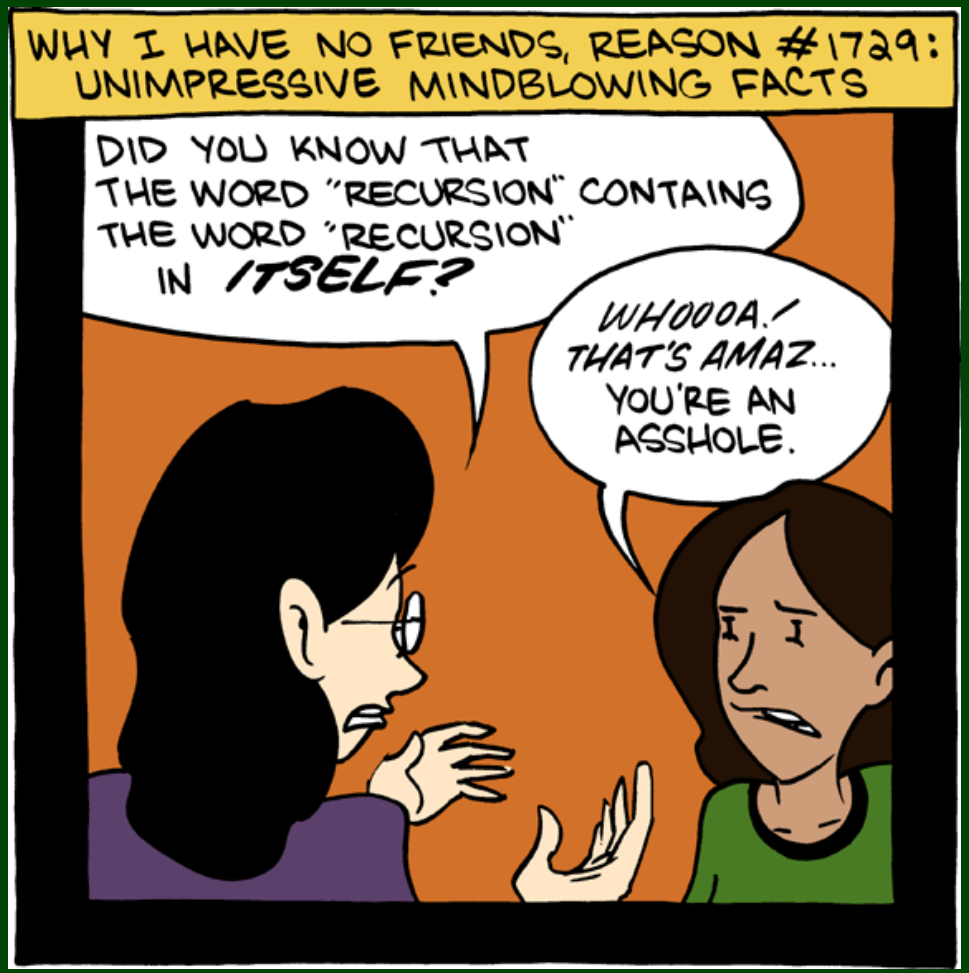
CSE 143

Computer Programming II

Recursive Backtracking



Outline

Definition (Recursive Backtracking)

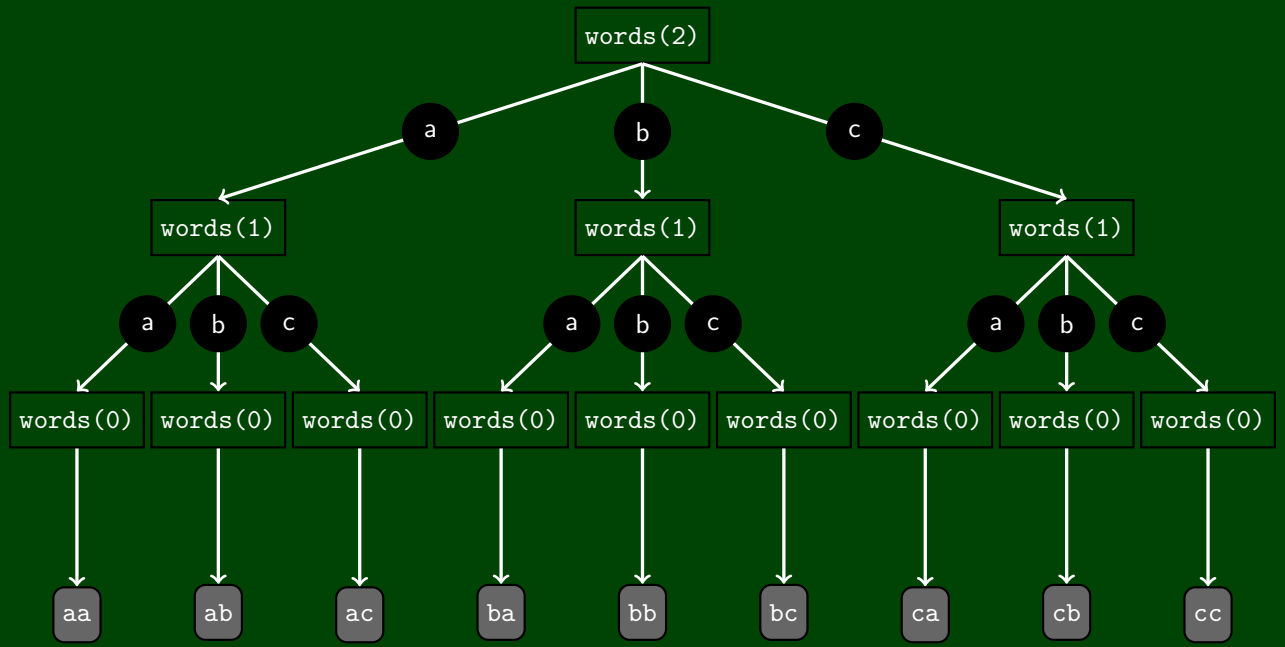
Recursive Backtracking is an attempt to find solution(s) by building up partial solutions and abandoning them if they don't work.

Recursive Backtracking Strategy

- If we found a solution, stop looking (e.g. return)
- Otherwise for each possible choice c...
  - Make the choice c
  - Recursively continue to make choices
  - Un-make the choice c (if we got back here, it means we need to continue looking)

All Words

Find all length n strings made up of a's, b's, and c's.



To do this, we build up partial solutions as follows:

- The only length 0 string is `""`; so, we're done.
- Otherwise, the three choices are a, b, and c:
  - Make the choice `letter`
  - Find all solutions with one fewer letter recursively.
  - Unmake the choice (to continue looking).

All Words Solution

```
 1 private static void words(int length) {
 2    String[] choices = {"a", "b", "c", "d"};
 3    // The empty string is the only word of length 0
 4    if (length == 0) {
 5       print();
 6    }
 7    else {
 8       // Try appending each possible choice to our partial word.
 9       for (String choice : choices) {
10          choose(choice);                    // Add the choice
11          words(length - 1);                 // Recurse on the rest
12          unchoose();                        // Undo the choice
13       }
14    }
15 }
```

Accumulators

```
 1  private static void words(String acc, int length) {
 2     String[] choices = {"a", "b", "c", "d"};
 3     // The empty string is the only word of length 0
 4     if (length == 0) {
 5        print();
 6     }
 7     else {
 8        for (String choice : choices) {
 9           acc += choice;
10           words(acc, length - 1);
11           acc = acc.substring(0, acc.length() - 1);
12        }
13     }
14  }
```

Solving Recursion Problems

- Figure out what the pieces of the problem are.
- What is the base case? (the smallest possible piece of the problem)
- Solve one piece of the problem and recurse on the rest.

`paintbucket` Review

- A piece of the problem is **one surrounding set of squares**
- The base case is **we hit a non-white cell**
- To solve one piece of the problem, we **color the cell** and **go left, right, up, and down**

Solving a maze is a lot like `paintbucket`. What is the difference?

Instead of filling everything in, we want to stop at dead ends!

If you were in a maze, how would you solve it?

- Try a direction.
- Every time you go in a direction, draw an X on the ground.
- If you hit a dead end, go back until you can go in another direction.

This is recursive backtracking!

```
 1 public boolean canSolveMaze(int x, int y) {
 2    if (isGoal(x, y)) {
 3       return true;
 4    }
 5    else if (inBounds(x, y) && isPassage(x, y)) {
 6       return solveMaze(x + 1, y) ||
 7              solveMaze(x - 1, y) ||
 8              solveMaze(x, y + 1) ||
 9              solveMaze(x, y - 1);
10    }
11 }
```

```
 1  public static boolean solveMaze(Point p) {
 2     // We found a path to the goal!
 3     if (p.isGoal()) {
 4        p.makeVisited(panel);
 5        return true;
 6     }
 7
 8     // If the point is a valid part of a path to the solution...
 9     if (!p.isOOB() && p.isPassage(panel)) {
10        p.makeVisited(panel);          // Choose this point
11        panel.sleep(120);
12        if (solveMaze(p.getLeft())  || // Try each direction
13            solveMaze(p.getRight()) || // until we get a
14            solveMaze(p.getAbove()) || // solution.
15            solveMaze(p.getBelow())) {
16           return true;
17        }
18        panel.sleep(200);
19        p.makeDeadEnd(panel);          // Undo the choice
20     }
21     return false;
22  }
```

Recursive Backtracking Tips!

- The most important part is figuring out what the choices are.
- It can help to draw out a tree of choices
- Make sure to undo your choices after the recursive call.
- You will still always have a base case.