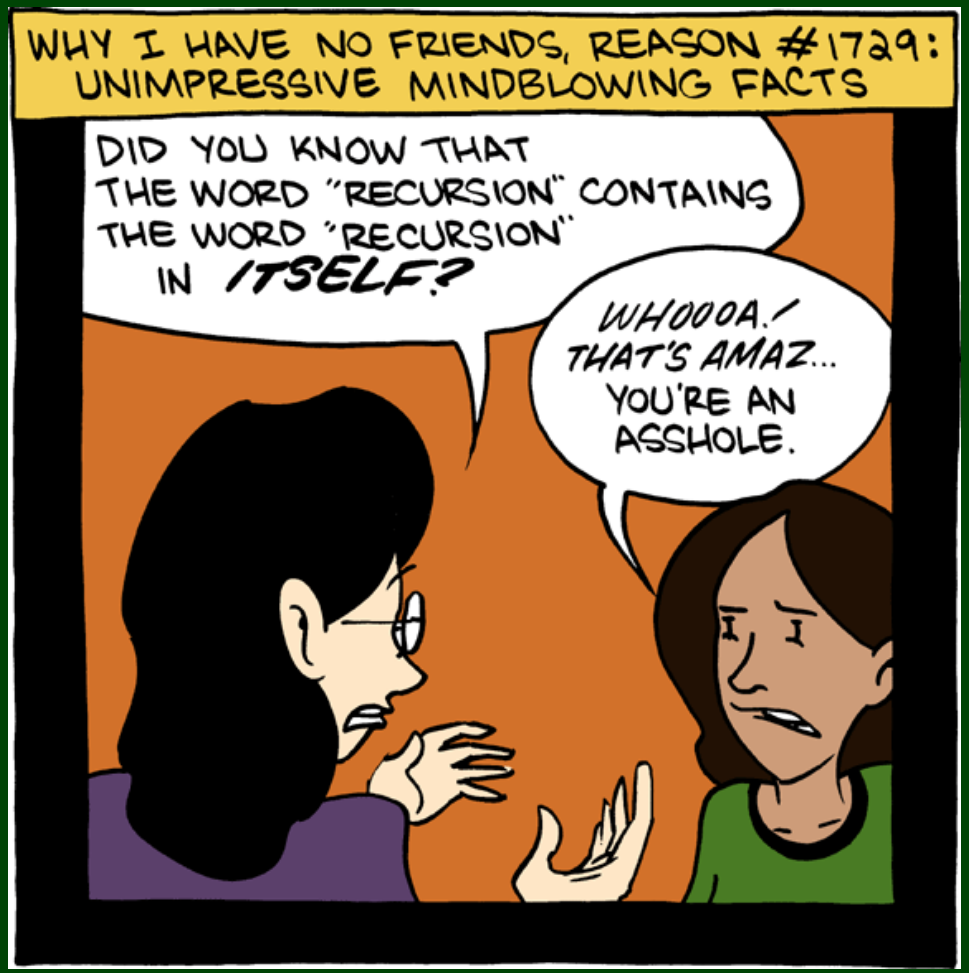
CSE 143

Computer Programming II

Recursive Backtracking



Outline

1 Words & Permutations

2 Solving Mazes

Definition (Recursive Backtracking)

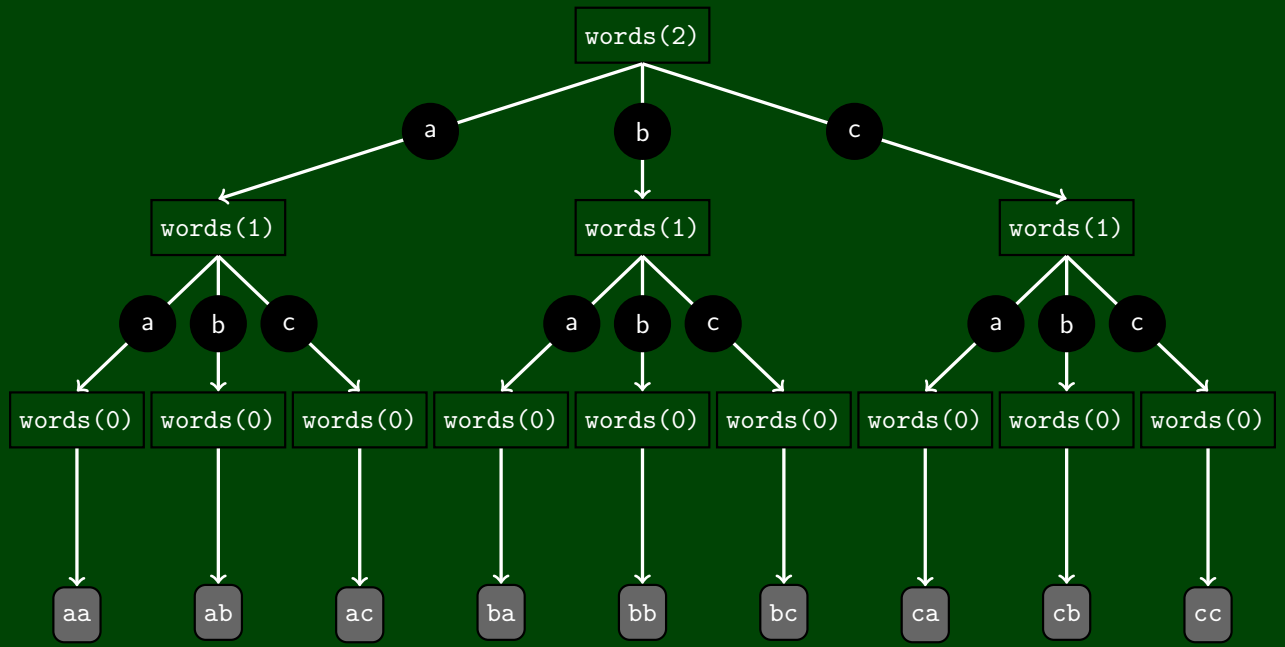
Recursive Backtracking is an attempt to find solution(s) by building up partial solutions and abandoning them if they don't work.

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.