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CSE 143

Computer Programming II

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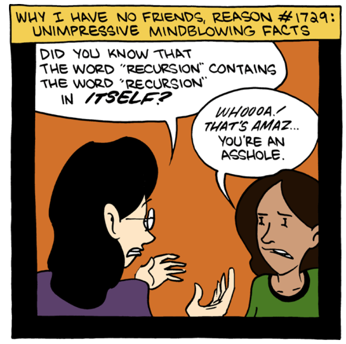
Recursive Backtracking



Outline

1 Solving Mazes

2 Words & Permutations

Recursion Reminder

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

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!

```java
public boolean canSolveMaze(int x, int y) {
   if (isGoal(x, y)) {
      return true;
   }
   else if (inBounds(x, y) && isPassage(x, y)) {
      return solveMaze(x + 1, y) ||
             solveMaze(x - 1, y) ||
             solveMaze(x, y + 1) ||
             solveMaze(x, y - 1);
   }
}
```

Solving a Maze


```java
public static boolean solveMaze(Point p) {
   // We found a path to the goal!
   if (p.isGoal()) {
      p.makeVisited(panel);
      return true;
   }

   // If the point is a valid part of a path to the solution...
   if (!p.isOOB() && p.isPassage(panel)) {
      p.makeVisited(panel);          // Choose this point
      panel.sleep(120);
      if (solveMaze(p.getLeft()) || // Try each direction
          solveMaze(p.getRight()) || // until we get a
          solveMaze(p.getAbove()) || // solution.
          solveMaze(p.getBelow())) {
         return true;
      }
      panel.sleep(200);
      p.makeDeadEnd(panel);          // Undo the choice
   }
   return false;
}
```

Recursive Backtracking

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.

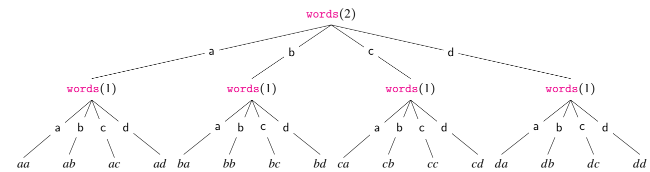
Recursive Backtracking Strategy

- 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)

Words & Permutations

All Words

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



To do this, we build up partial solutions as follows:
(Assume there is a variable `part` that is initialized to `""`.)

- The only length 0 string is `""`; so, `part` is a solution.
- Otherwise, the four choices are a, b, c, and d:
  - To make the choice `letter`, we set `part += letter`.
  - Then, we need to find all solutions with one fewer letter recursively.
  - Now, we unmake the choice (to continue looking) by removing `letter` from `part`.

All Words Solution

```java
String part = "";
private static void words(int length) {
   String[] choices = {"a", "b", "c", "d"};
   // The empty string is the only word of length 0
   if (length == 0) {
      System.out.println(part);
   }
   else {
      // Try appending each possible choice to our partial word.
      for (String choice : choices) {
         part += choice;                        // Add the choice
         words(length − 1);                     // Recurse on the rest
         int size = part.length()
         part = part.substring(0, size − 1);    // Undo the choice
      }
   }
}
```

Permutations

How do we change `words` to only print out words that have each character exactly once?

Permutations Solution

Idea: When a solution becomes "bad" (it has multiple of the same letter), stop trying that branch.

```java
String part = "";
private static void permutations(int length) {
   String[] choices = {"a", "b", "c", "d"};
   // If we have a repeat letter, the solution is invalid.
   if (hasRepeats(part)) {
      return;
   }
   else if (length == 0) {
      System.out.println(part);
   }
   else {
      for (String choice : choices) {
         part += choice;
         permutations(length − 1);
         int size = part.length()
         part = part.substring(0, size − 1);
      }
   }
}
```

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.