Programming Abstractions

CS106B

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Today's topics:

- Previous lecture:
  - Loops + recursion for *generating sequences and combinations*
- Today:
  - Loops + recursion for *recursive backtracking*

#MeToo

Backtracking

Maze solving

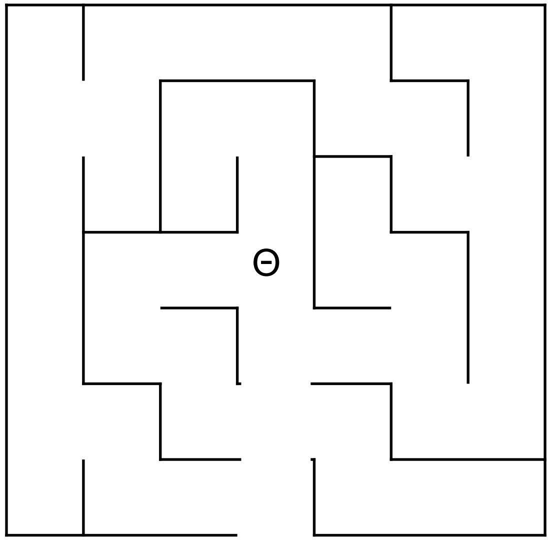
Stanford University

Backtracking

A particular behavior in recursive code where you tentatively explore many options, and recover to the nearest junction when you hit a “dead end,” so you can try a different path from that junction

The easiest way to understand this is probably to see literal exploration and dead ends

Maze-solving



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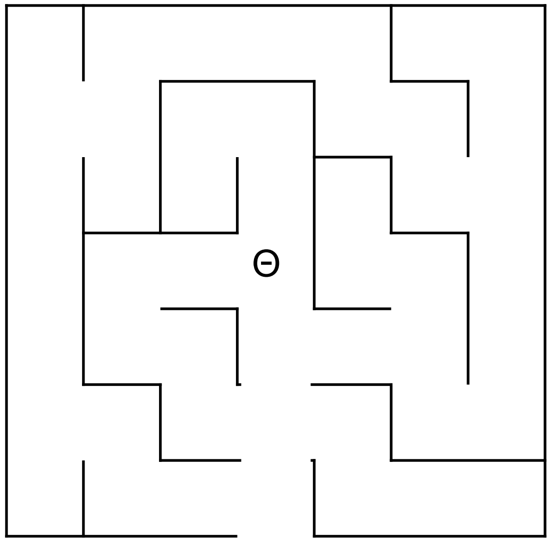
Maze-solving



Thinking through the pseudo-code:

- Return true if there is a way to win from where we're standing.
- Return false if there isn't.

- *From the start position, this amounts to saying, return true if there a way to solve the whole maze, otherwise false.*

Backtracking template

- **bool backtrackingRecursiveFunction*(args)* {**
  - Base case test for success: return true
  - Base case test for failure: return false
  - Loop over several options for “what to do next”:
    - Tentatively “do” one option
    - if (recursiveFunction() returns true) return true
    - else That tentative idea didn’t work, so “undo” that option
  - None of the options we tried in the loop worked, so return false

SolveMaze code

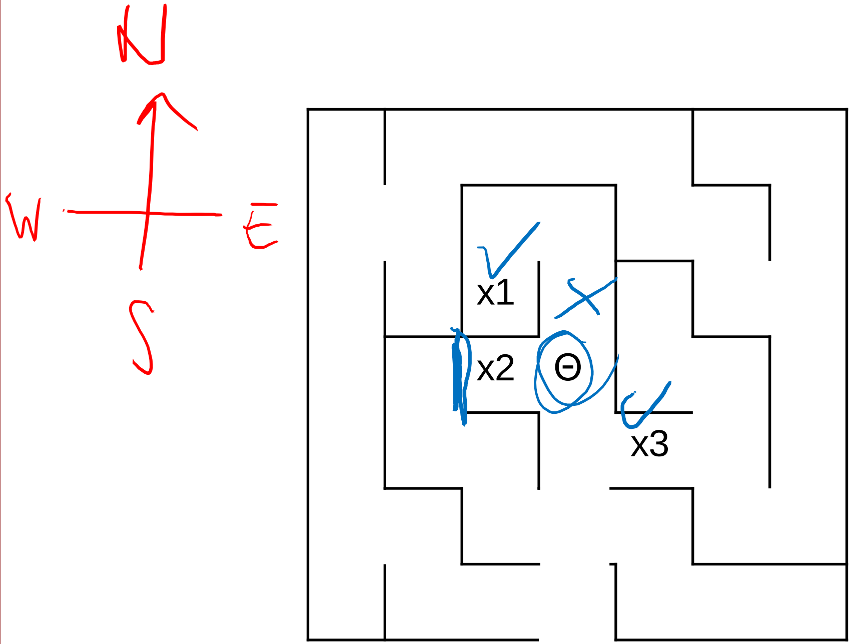
Adapted from the textbook by Eric Roberts

```
bool solveMaze(Maze & maze, Point start) {
   if (maze.isOutside(start)) return true;
   if (maze.isMarked(start)) return false;
   maze.markSquare(start);
   pause(200);
   for (Direction dir = NORTH; dir <= WEST; dir++) {
      if (!maze.wallExists(start, dir)) {
         if (solveMaze(maze, adjacentPoint(start, dir))) {
            return true;
         }
      }
   }
   maze.unmarkSquare(start);
   return false;
}
```

```
enum Direction =
{NORTH, EAST, SOUTH,
WEST};
```

```
//order of for loop:
enum Direction =
{NORTH, EAST, SOUTH, WEST};
```

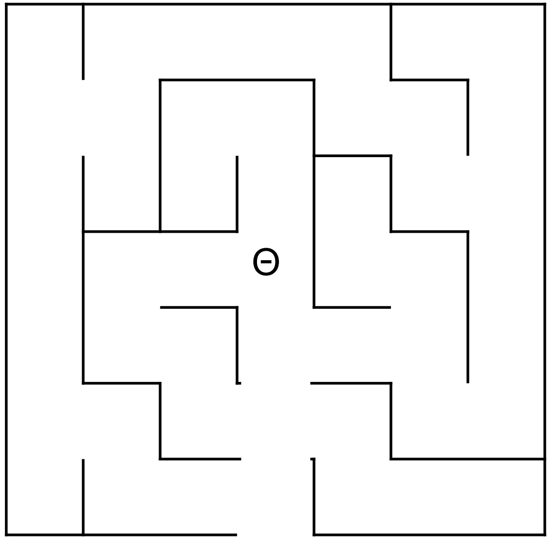
Maze-solving



In what order do we visit these spaces?

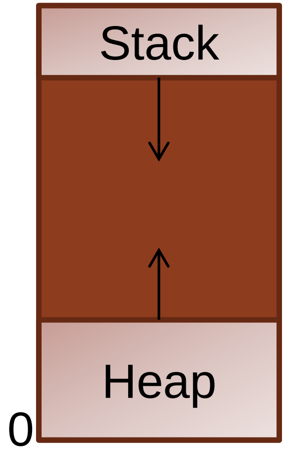
A. x1, x2, x3
B. x2, x3, x1
[✓ C. x1, x3, x2]
D. We don’t visit all three
E. Other/none/more

The stack



What is the deepest the Stack gets (number of stack frames) during the solving of this maze?

A. Less than 5
B. 5-10
C. 11-20
[✓ D. More than 20]
E. Other/none/more



Contrast: Recursive maze-solving vs. Word ladder

- With word ladder, you did **breadth-first search**
- This problem uses **depth-first search**

- Both are possible for maze-solving!

- The contrast between these approaches is a theme that you'll see again and again in your CS career

Contrast: Recursive maze-solving vs. Word ladder

- With word ladder, you did **breadth-first search (BFS)**
  - **Used a QUEUE of ladders**
- This problem uses **depth-first search (DFS)**
  - **Uses a STACK of locations (implicitly)**
  - Can also do DFS with an explicit stack
- Both are possible for maze-solving!
- The contrast between these approaches is a theme that you'll see again and again in your CS career