CSC 211: Object Oriented Programming

(Recursive) Backtracking

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Spring 2020

THINK BIG WE DO℠

Images and material from web.stanford.edu

Recursion Reminder

- Problem solving technique in which we solve a task by reducing it to smaller tasks (of the same kind)
  - then use same approach to solve the smaller tasks
- Technically, a recursive function is one that **calls itself**
- General form:
  - **base case**
    - solution for a **trivial case**
    - it can be used to stop the recursion (prevents "*stack overflow*")
    - every recursive algorithm needs at least one base case
  - **recursive call(s)**
    - divide problem into **smaller instance(s)** of the **same structure**

Recursion Reminder

- Recursive Checklist:
  - **Find what information we need to keep track of.** What inputs/outputs are needed to solve the problem at each step?
  - **Find our base case(s).** What are the simplest (nonrecursive) instance(s) of this problem?
  - **Find our recursive step.** How can this problem be solved in terms of one or more simpler instances of the same problem that lead to a base case?
  - **Ensure every input is handled.** Do we cover all possible cases? Do we need to handle errors?

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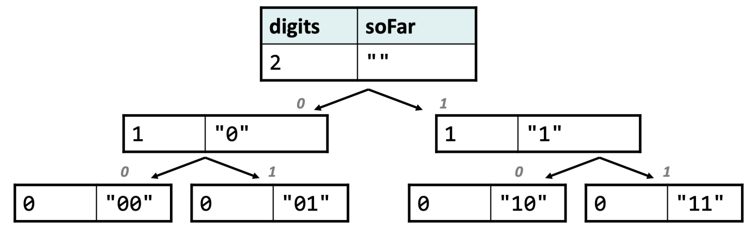
Backtracking

- Write a recursive function printAllBinary that accepts an integer number of digits and prints all binary numbers that have exactly that many digits, in ascending order, one per line

printAllBinary(2);	printAllBinary(3);
00	000
01	001
10	010
11	011
	100
	101
	110
	111

Backtracking

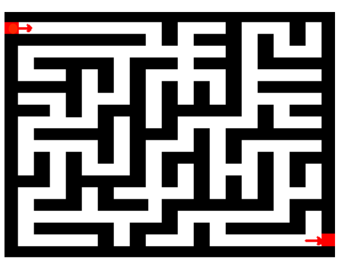
printAllBinary(2);



- This kind of diagram is called a **call tree** or **decision tree**
- Think of each call as a choice or decision made by the algorithm:
  - Should I choose 0 as the next digit?
  - Should I choose 1 as the next digit?
- The idea is to try every permutation. For every position, there are 2 options, either '0' or '1'. **Backtracking** can be used in this approach to try every possibility or permutation to generate the correct set of strings.

Backtracking

- **Recursive Backtracking**: using recursion to explore solutions to a problem and abandoning them if they are not suitable
-



Backtracking

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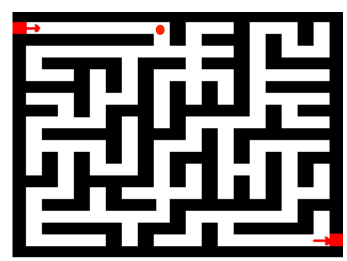

Backtracking

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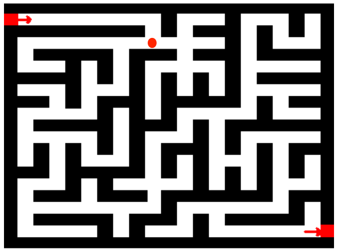

Backtracking

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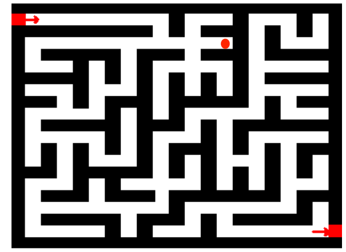

Backtracking

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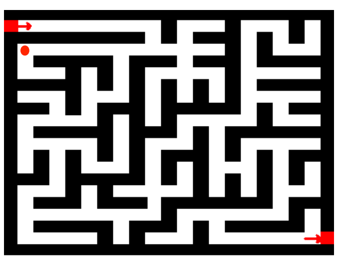

Backtracking

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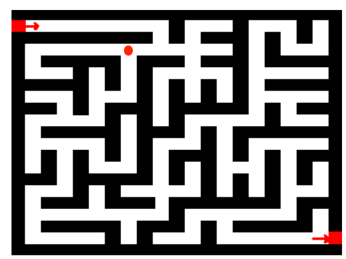

Backtracking

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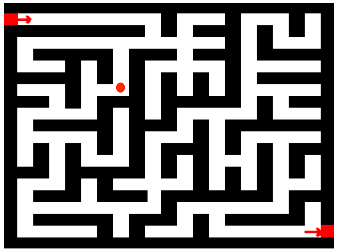

Backtracking

- Let's take a look at a problem similar to the binarySequence problem.
- Write a recursive function diceRoll that accepts an integer representing a number of 6-sided dice to roll, and output all possible combinations of values that could appear on the dice.

diceRoll(2)

{1,1}	{3, 1}	{5, 1}
{1, 2}	{3, 2}	{5, 2}
{1, 3}	{3, 3}	{5, 3}
{1, 4}	{3, 4}	{5, 4}
{1, 5}	{3, 5}	{5, 5}
{1, 6}	{3, 6}	{5, 6}
{2, 1}	{4, 1}	{6, 1}
{2, 2}	{4, 2}	{6, 2}
{2, 3}	{4, 3}	{6, 3}
{2, 4}	{4, 4}	{6, 4}
{2, 5}	{4, 5}	{6, 5}
{2, 6}	{4, 6}	{6, 6}

Backtracking

- Backtracking Checklist:
  - ✓ **Find what choice(s) we have at each step.** What different options are there for the next step?

    For each valid choice:
    - **Make it and explore recursively.** Pass the information for a choice to the next recursive call(s).
    - **Undo it after exploring.** Restore everything to the way it was before making this choice.
  - ✓ **Find our base case(s).** What should we do when we are out of decisions?

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What die value should I choose next?

Backtracking

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  - Undo it after exploring. Restore everything to the way it was before making this choice.
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```
We need to communicate
the dice chosen so
far to the next
recursive call
```


Backtracking

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  For each valid choice:
  - Make it and explore recursively. Pass the information for a choice to the next recursive call(s).
  - **Undo it after exploring.** Restore everything to the way it was before making this choice.
  - Find our base case(s). What should we do when we are out of decisions?

```
We need to be able to
remove the die we added
to our first roll so far
```


Backtracking

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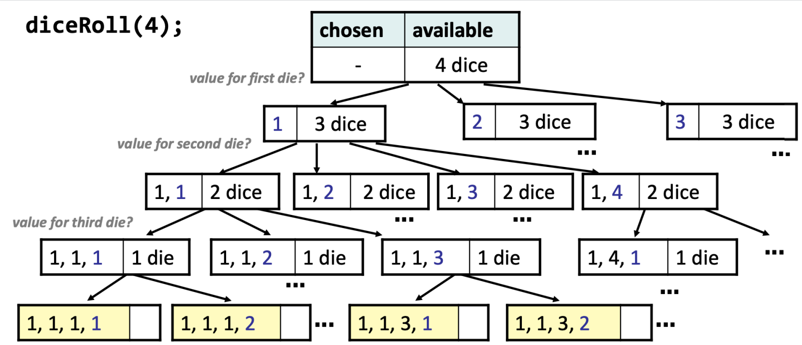
  - Find what choice(s) we have at each step. What different options are there for the next step?

  For each valid choice:
  - Make it and explore recursively. Pass the information for a choice to the next recursive call(s).
  - Undo it after exploring. Restore everything to the way it was before making this choice.
  - **Find our base case(s).** What should we do when we are out of decisions?

```
We have no dice
left to choose,
print them out
```


Backtracking

`diceRoll(4);`



- Observations?
- This is a really big search space.
- Depending on approach, we can make wasteful decisions. Can we optimize it? Yes. Will we right now? No.

Backtracking

- **Pseudocode**

- function diceRolls(dice):

```
    if dice == 0:
        nothing to do.
    else:
        // handle all roll values for a single die; let recursion do the rest.
        for each die value i in range [1..6]:
            choose that the current die will have value i
            // explore the remaining dice
            diceRolls(dice-1)
            un-choose (backtrack) the value I
```

** Need to keep track of our choices somehow