LEC 13

CSE 123

Exhaustive Search / Recursive Backtracking

Questions during Class?

Raise hand or send here

sli.do #cse123

BEFORE WE START

Talk to your neighbors:

What's your favorite refreshing summer drink?

Music: [123 24su Lecture Tunes]

Instructor: Joe Spaniac

TAs: Andras Daniel Eric Nicole Sahej Trien Zach

Lecture Outline

- Announcements ◀
- Exhaustive Search
  - Decision trees
  - Password Cracking
  - Dead ends
- Recursive Backtracking
  - Cipher Cracking

Announcements

- Resubmission Period 5 due tonight (8/2) at 11:59pm
- Programming Assignment 3 due Wednesday (8/7) at 11:59pm
- Resubmission Period 6 opening tonight, due next Friday (8/9)
  - Assignments available: P2, C3
- Last day of content on the final!
  - Next week: Machine learning (ML) + SpamClassifier / Hashing
  - Useful content, especially if you’re continuing to study CS
- Reminder: Grade Guarantee Calculator
  - You’ve received many, many grades throughout this quarter
  - Should have a good idea of what GPA you’re guaranteed

Lecture Outline

- Announcements
- **Exhaustive Search** ◀
  - Decision trees
  - Password Cracking
  - Dead ends
- Recursive Backtracking
  - Cipher Cracking

Exhaustive Search

- Last application of recursion for the quarter!
- There are some problems computers are bad at solving
  - Polynomial vs. Nonderministic Polynomial (P vs. NP)
- Password cracking / decrypting is a great example
  - If breaking these were easy, the internet wouldn’t be useable
- So what do we do?
  - The stupid way of solving the problem
  - We “exhaustively search” through every possibility
- What do we need? Recursion + String accumulator (public / private pair)

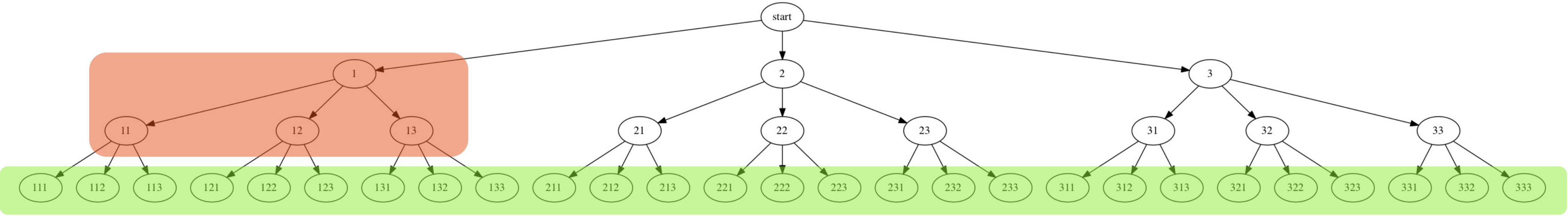
Exhaustive Search Pattern

```
public static void search(input) {
    search(input, “”);
}

private static void search(input, String soFar) {
    if (base case) {
        // Do something with soFar (e.g. print it out)
        System.out.println(soFar);
    } else {
        // Might not be a loop, but 1 recursive call for each option
        for (each option) {
            search(input, soFar + option);
        }
    }
}
```

Decision Trees

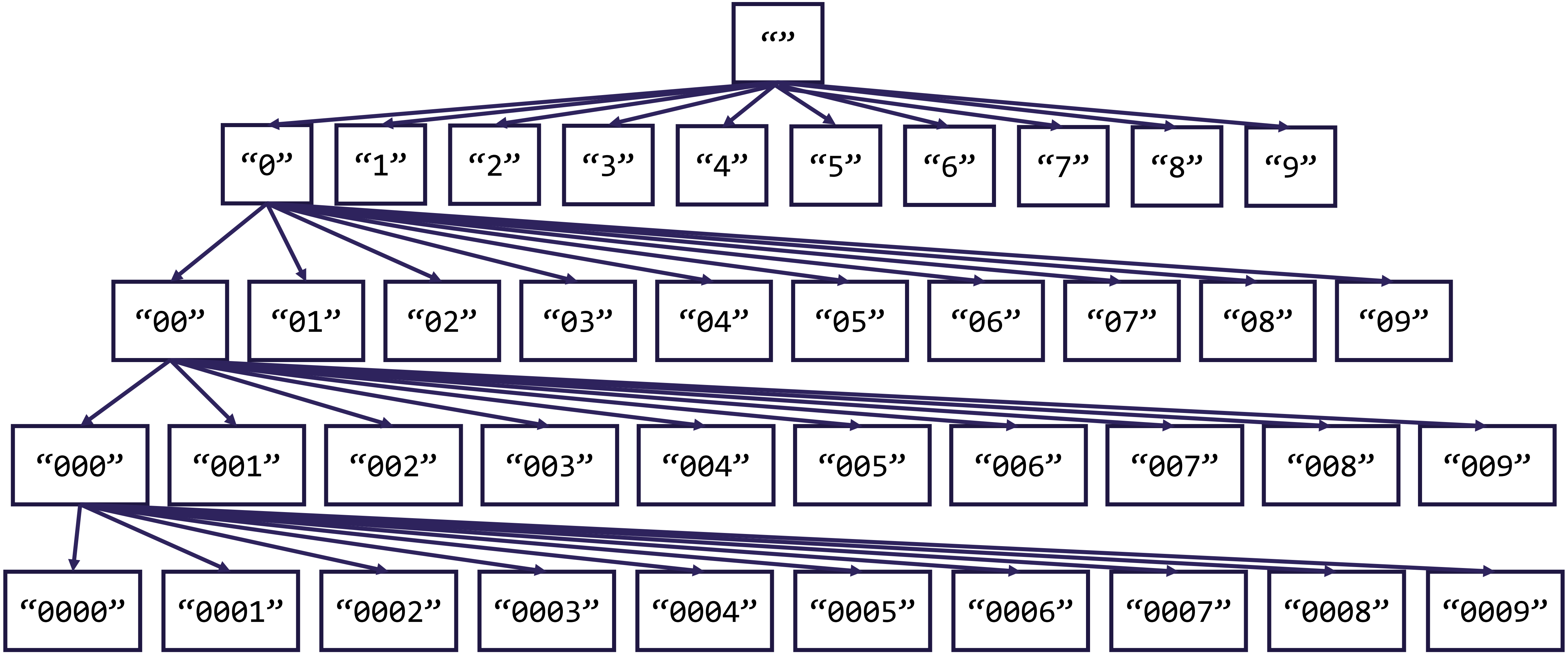
- Visual we use to help understand what our process is
  - Not a data structure like a Binary Tree, just a visualization tool
  - If you can make a decision tree you can implement exhaustive search



- Can glean important information
  - **Base case (end nodes)**
  - **Recursive case (middle nodes)**
  - **"Dead end" case (more on this later…)**

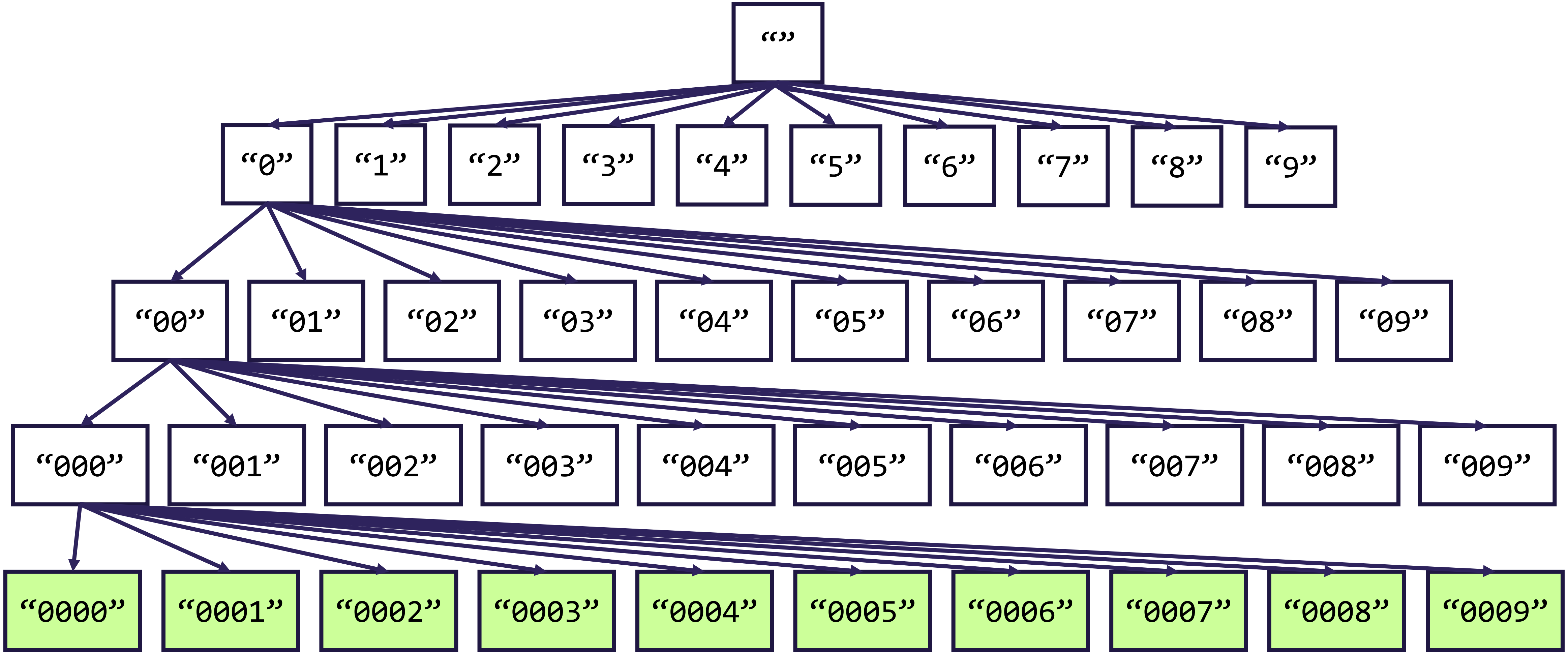
Password Cracker

- Let’s say we want to crack the password of a 4 digit combination lock



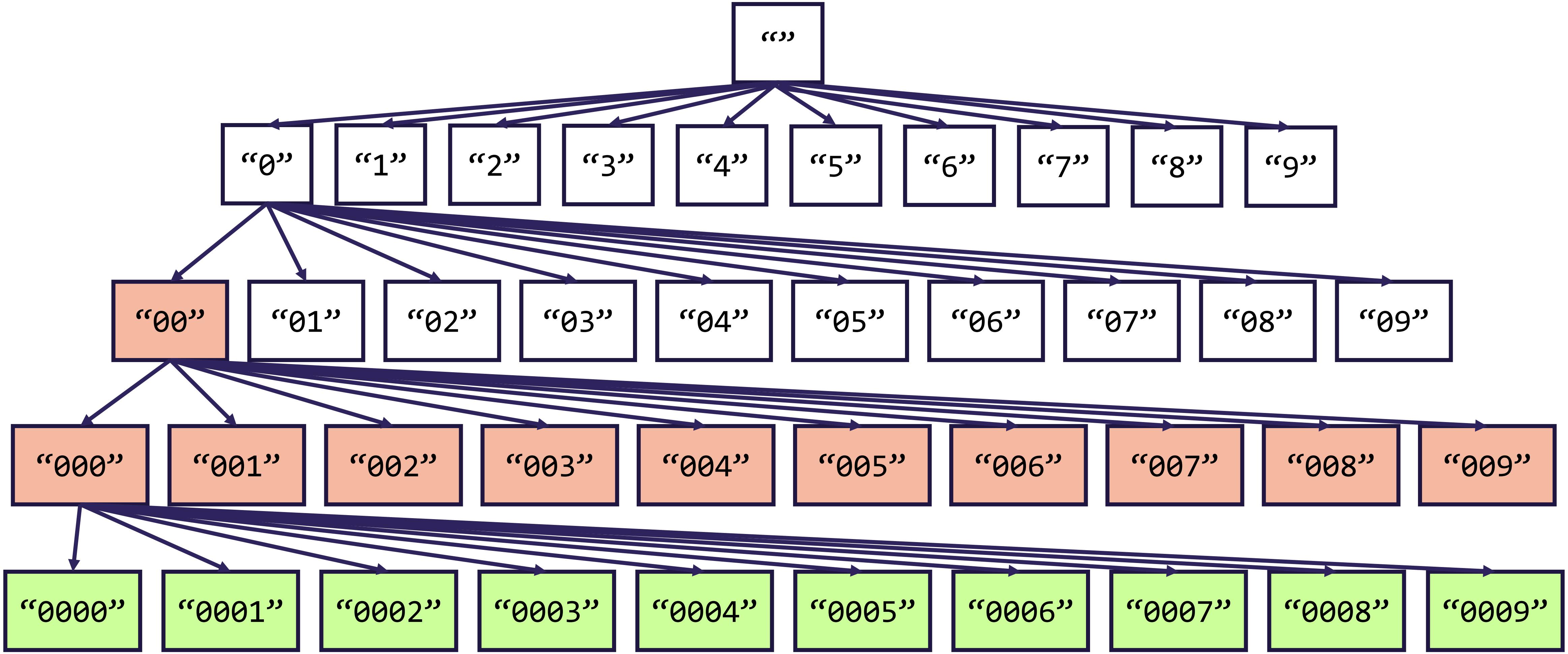
Password Cracker

- Let’s say we want to crack the password of a 4 digit combination lock



Password Cracker

- Let’s say we want to crack the password of a 4 digit combination lock

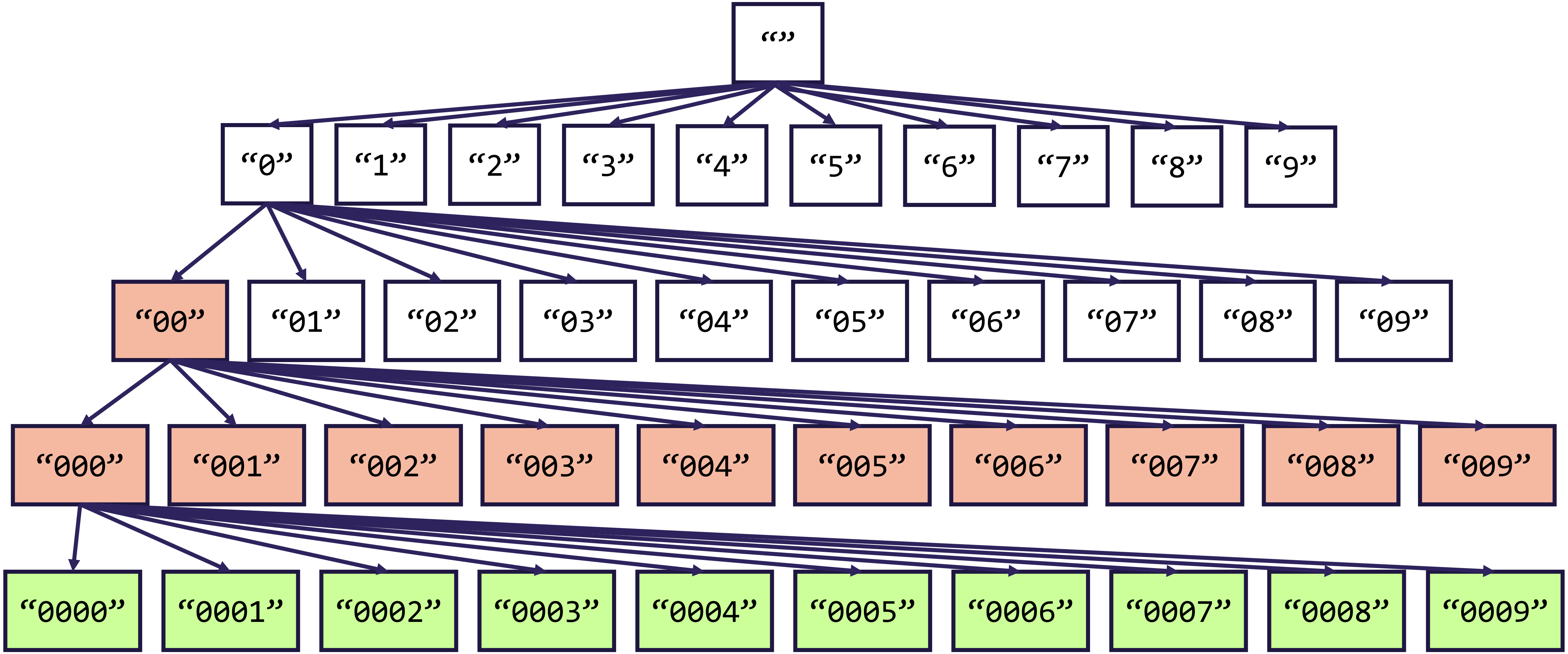


Lecture Outline

- Announcements
- Exhaustive Search
  - Decision trees
  - **Password Cracking**
  - Dead ends
- Recursive Backtracking
  - Cipher Cracking

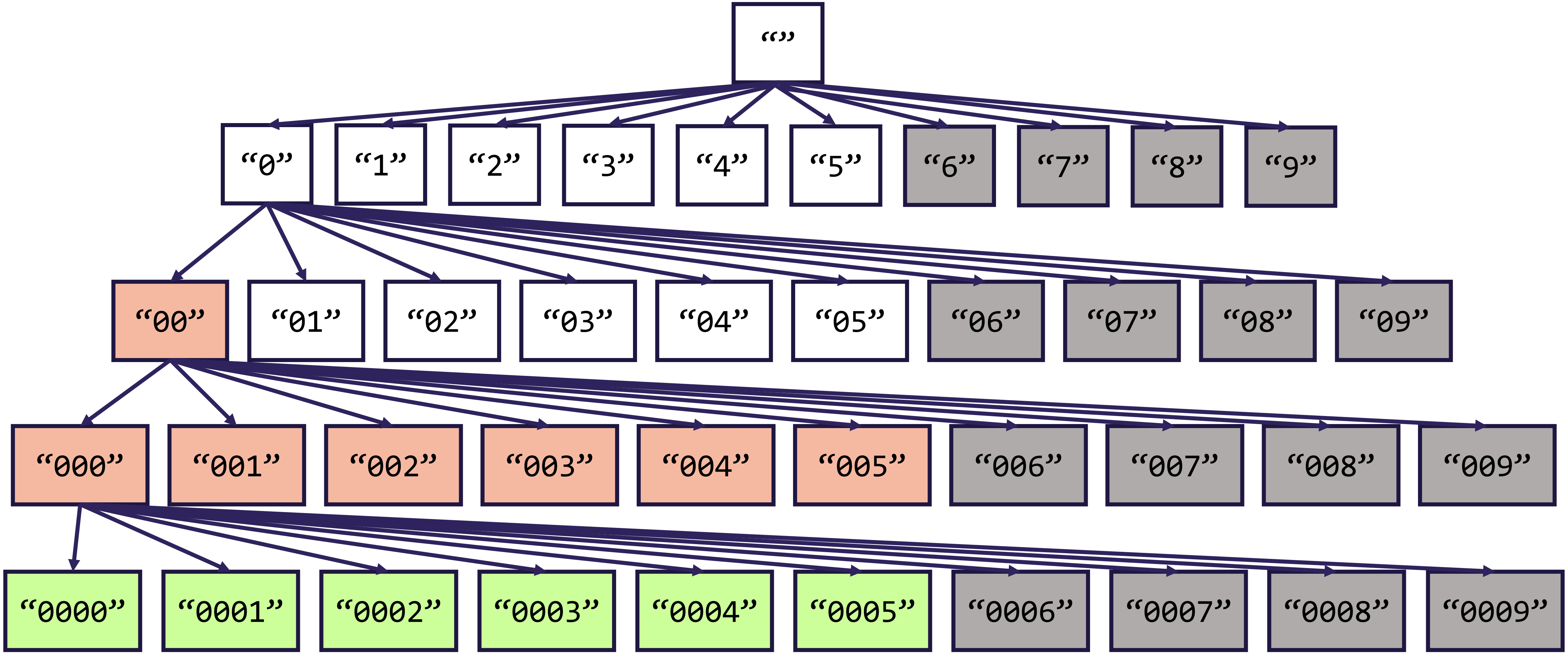
Password Cracker

- Now, what if we knew the sum of all digits was 5?



Password Cracker

- Now, what if we knew the sum of all digits was 5?



Updated Exhaustive Search Pattern

```
public static void search(input) {
    search(input, “”);
}

private static void search(input, String soFar) {
    if (base case) {
        // Do something with soFar (e.g. print it out)
        System.out.println(soFar);
    } else if (not dead end) {
        // Might not be a loop, but 1 recursive call for each option
        for (each option) {
            search(input, soFar + option);
        }
    }
}
```

Lecture Outline

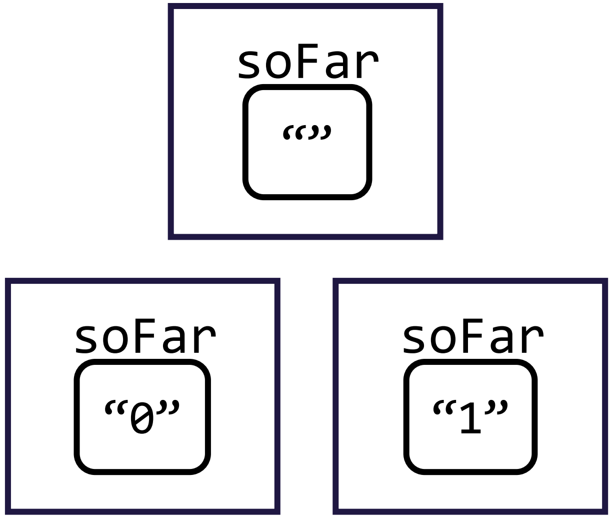
- Announcements
- Exhaustive Search
  - Decision trees
  - Password Cracking
  - Dead ends
- **Recursive Backtracking**
  - Cipher Cracking

Recursive Backtracking

- Exhaustive search with a data structure accumulator(s)
  - Now we have to deal with reference semantics…
- Major pattern: **Choose, Explore, Un-choose**
  - All of the stack frames share the same *one* data structure
  - Need to explicitly un-choose it so it’s not remembered in other frames

```
String soFar:

for (each option) {
    search(input, soFar + option);
}
```

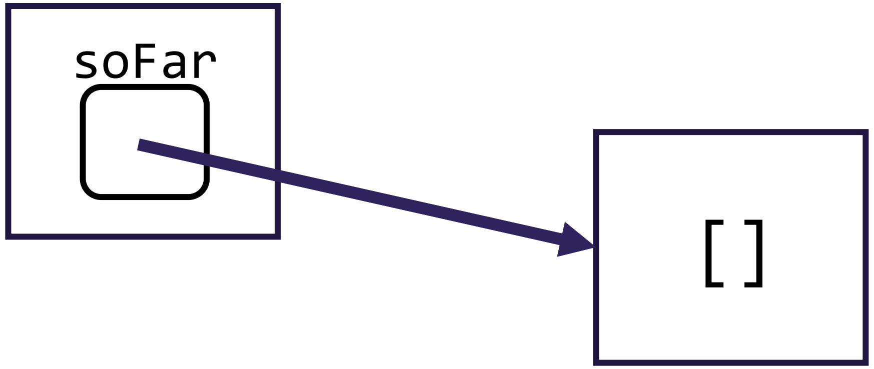


Recursive Backtracking

- Exhaustive search with a data structure accumulator(s)
  - Now we have to deal with reference semantics…
- Major pattern: **Choose, Explore, Un-choose**
  - All of the stack frames share the same *one* data structure
  - Need to explicitly un-choose it so it's not remembered in other frames

```
List<Character> soFar:

for (each option) {
    soFar.add(option);
    search(input, soFar);
    soFar.remove(soFar.size() – 1);
}
```

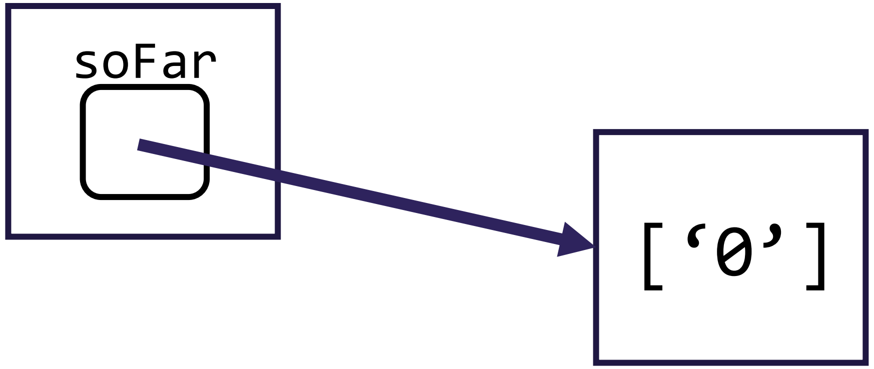


Recursive Backtracking

- Exhaustive search with a data structure accumulator(s)
  - Now we have to deal with reference semantics…
- Major pattern: **Choose, Explore, Un-choose**
  - All of the stack frames share the same *one* data structure
  - Need to explicitly un-choose it so it's not remembered in other frames

```
List<Character> soFar:

for (each option) {
    soFar.add(option);
    search(input, soFar);
    soFar.remove(soFar.size() – 1);
}
```

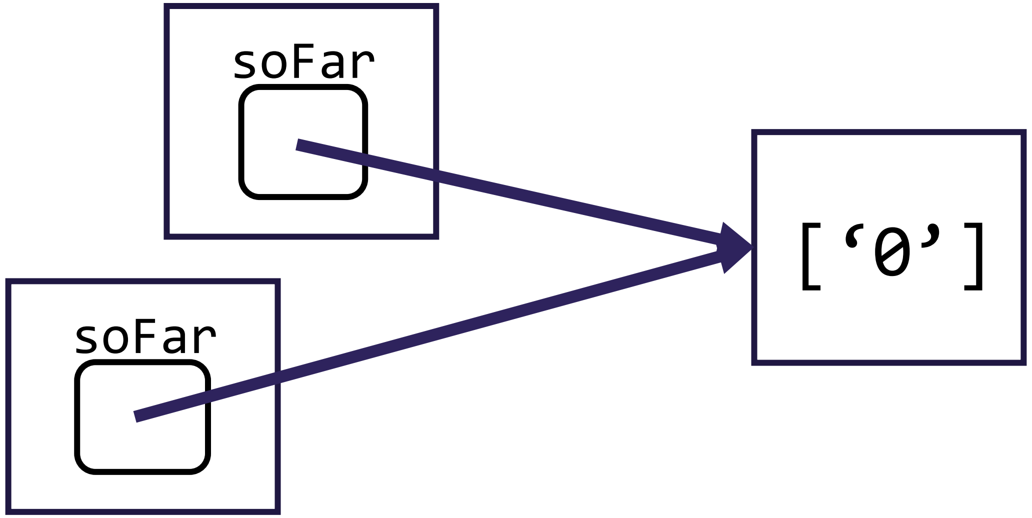


Recursive Backtracking

- Exhaustive search with a data structure accumulator(s)
  - Now we have to deal with reference semantics…
- Major pattern: **Choose, Explore, Un-choose**
  - All of the stack frames share the same *one* data structure
  - Need to explicitly un-choose it so it’s not remembered in other frames

```
List<Character> soFar:

for (each option) {
    soFar.add(option);
    search(input, soFar);
    soFar.remove(soFar.size() – 1);
}
```

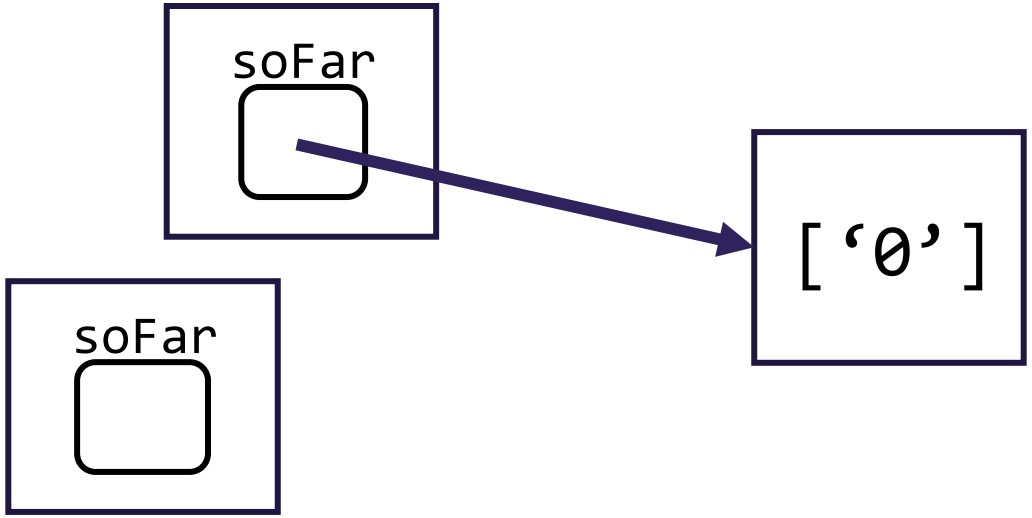


Recursive Backtracking

- Exhaustive search with a data structure accumulator(s)
  - Now we have to deal with reference semantics…
- Major pattern: **Choose, Explore, Un-choose**
  - All of the stack frames share the same *one* data structure
  - Need to explicitly un-choose it so it’s not remembered in other frames

```
List<Character> soFar:

for (each option) {
    soFar.add(option);
    search(input, soFar);
    soFar.remove(soFar.size() – 1);
}
```

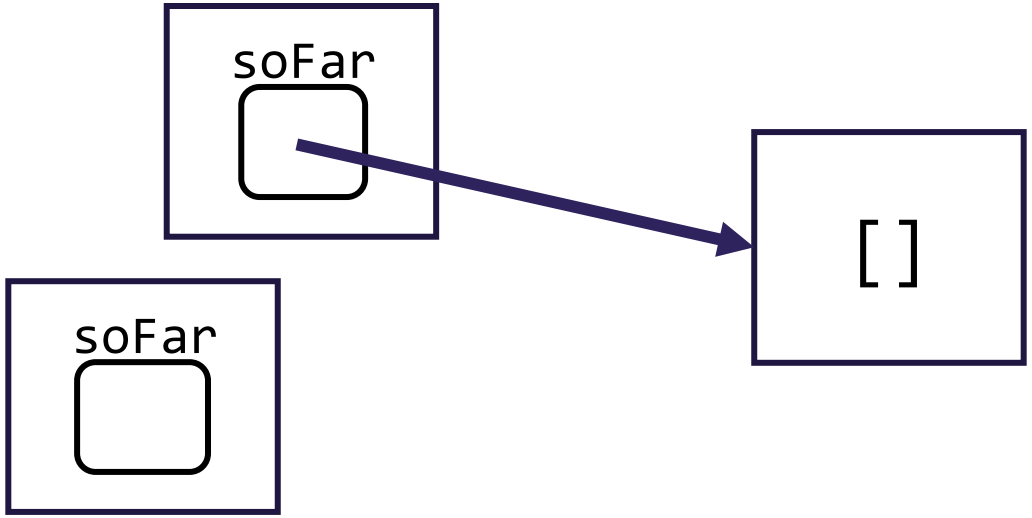


Recursive Backtracking

- Exhaustive search with a data structure accumulator(s)
  - Now we have to deal with reference semantics…
- Major pattern: **Choose, Explore, Un-choose**
  - All of the stack frames share the same *one* data structure
  - Need to explicitly un-choose it so it's not remembered in other frames

```
List<Character> soFar:

for (each option) {
    soFar.add(option);
    search(input, soFar);
    soFar.remove(soFar.size() - 1);
}
```

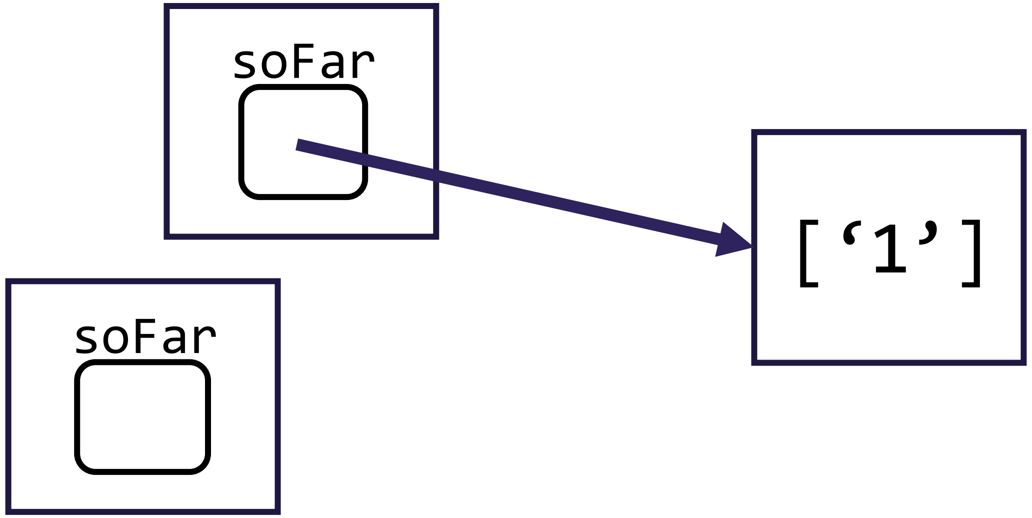


Recursive Backtracking

- Exhaustive search with a data structure accumulator(s)
  - Now we have to deal with reference semantics…
- Major pattern: **Choose, Explore, Un-choose**
  - All of the stack frames share the same *one* data structure
  - Need to explicitly un-choose it so it’s not remembered in other frames

```
List<Character> soFar:

for (each option) {
    soFar.add(option);
    search(input, soFar);
    soFar.remove(soFar.size() – 1);
}
```

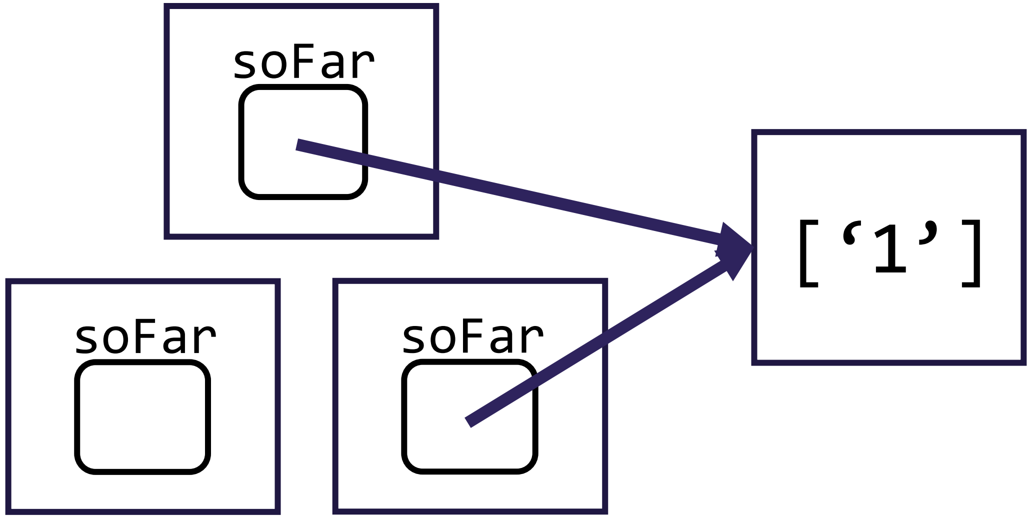


Recursive Backtracking

- Exhaustive search with a data structure accumulator(s)
  - Now we have to deal with reference semantics…
- Major pattern: **Choose, Explore, Un-choose**
  - All of the stack frames share the same *one* data structure
  - Need to explicitly un-choose it so it's not remembered in other frames

```
List<Character> soFar:

for (each option) {
    soFar.add(option);
    search(input, soFar);
    soFar.remove(soFar.size() – 1);
}
```

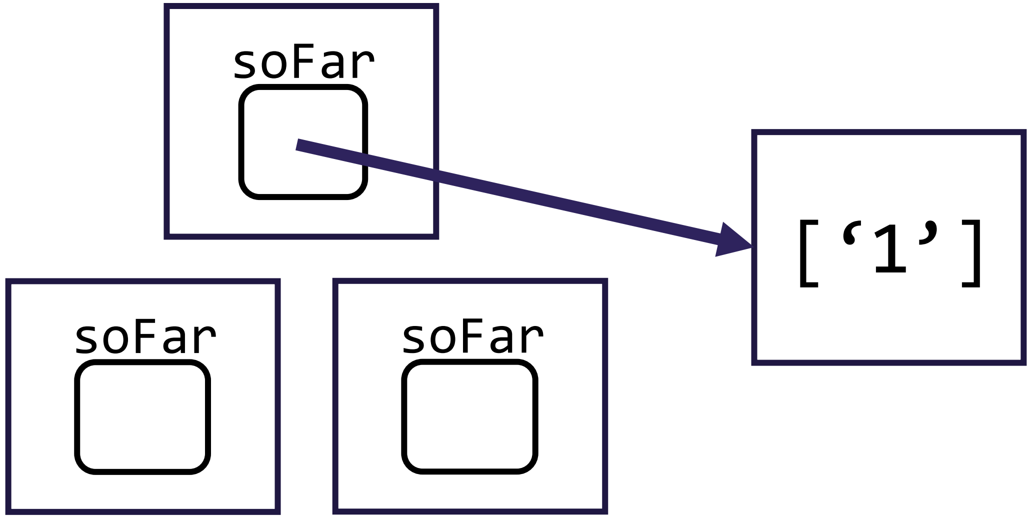


Recursive Backtracking

- Exhaustive search with a data structure accumulator(s)
  - Now we have to deal with reference semantics…
- Major pattern: **Choose, Explore, Un-choose**
  - All of the stack frames share the same *one* data structure
  - Need to explicitly un-choose it so it's not remembered in other frames

```
List<Character> soFar:

for (each option) {
    soFar.add(option);
    search(input, soFar);
    soFar.remove(soFar.size() - 1);
}
```

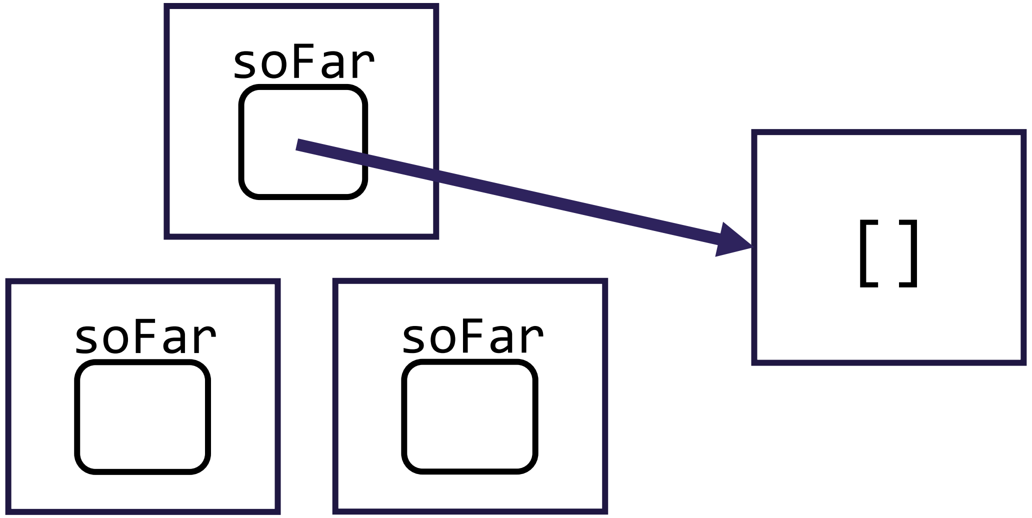


Recursive Backtracking

- Exhaustive search with a data structure accumulator(s)
  - Now we have to deal with reference semantics…
- Major pattern: **Choose, Explore, Un-choose**
  - All of the stack frames share the same *one* data structure
  - Need to explicitly un-choose it so it's not remembered in other frames

```
List<Character> soFar:

for (each option) {
    soFar.add(option);
    search(input, soFar);
    soFar.remove(soFar.size() - 1);
}
```



Recursive Backtracking Pattern

```
private static void search(input, List<Character> soFar) {
    if (base case) {
        // Do something with soFar (e.g. print it out)
        System.out.println(soFar);
    } else if (not dead end) {
        // Might not be a loop, but 1 recursive call for each option
        for (each option) {
            soFar.add(option);                  // Choose
            search(input, soFar);               // Explore
            soFar.remove(soFar.size() - 1);     // Unchoose
        }
    }
}
```

Lecture Outline

- Announcements
- Exhaustive Search
  - Decision trees
  - Password Cracking
  - Dead ends
- Recursive Backtracking
  - **Cipher Cracking** ◀