CS 61A SU26

Lecture 09: Trees

July 6, 2026

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Join pollev.com/rebeccadang831 (or scan QR code) on your phone or laptop

We'll begin at Berkeley time (10 minutes after), as per tradition!

Potpourri

5 min

- Announcements
- Lecture 08 Follow-Up
- Computing in the News

Announcements

- Quiz 2 happening today and tomorrow
- Upon request, I've added the **PollEv full question text and answer options** in speaker notes 🎉
  - Alternatively, watch recording on bCourses
- **New OH hours and locations**, check the OH calendar (for all staff + instructor)
  - Ed post
  - Instructor OH:
    - Tue 1-2 pm moved to **Cory 540AB starting tomorrow**
    - Thu 7-8 pm moved to **Cory 521 starting next week** (still in Soda 347 this week)
  - Instructor Tea Hours: Wed 11:30 am - 12:30 pm still Soda 795 this week, but **subject to change starting next week** (hoping for Cory room)
- **Additional Exam Prep** sections available
  - **Caution**: Read the Ed post to see when the new sections start
- **Student support** meetings available
- No post-lecture questions today

[out of scope] Lecture 08 Follow-Up

Python dictionary implementation

- TLDR: it's just a hash table with open addressing and some space optimizations
- Blogs in increasing level of detail; they may be outdated...
  - How are Python's Built In Dictionaries Implemented? (StackOverflow)
  - Python dictionary, the implementation
  - Python behind the scenes #10: how Python dictionaries work
- More in CS 61B!

Computing in the News

- ‘Who Should I Vote for?’ Voters Turn to A.I. Before Casting Their Ballots (New York Times)
- UC Berkeley shows no signs of AI grade inflation as professors adapt (Daily Cal)

Review

10 min

- Dictionaries
- ADTs

Practice: Flip Dict

- Implement `flip_dict`
  - Hint: To check if something is a particular data type in Python, you can do:
    - `type(<expression>) is <type>` or
    - `type(<expression>) == <type>` (less preferred) or
    - `isinstance(<expression>, <type>)`
- Download starter code `09.py` from the course website under Lecture 9
- Run doctests with `python3 -m doctest 09.py`
- 5 min: Try implementing it yourself
- 5 min: Discuss with someone next to you and compare your implementations
  - What worked?
  - What didn't?
  - Why?

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Consider the Coordinate ADT we implemented in Lecture 08. Which of the following functions are behind the abstraction barrier (e.g. part of the ADT)?

Trees

15 min

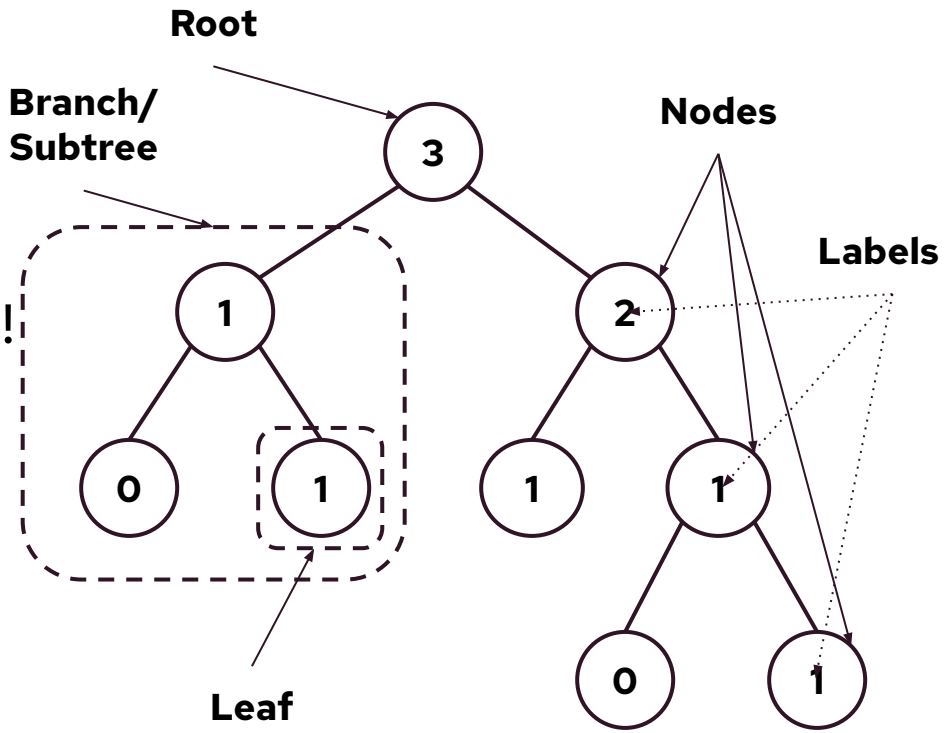
- Definition
- Motivation
- Tree Terminology
- Tree ADT

Definition (1 of 2)

A **tree** is a data structure comprised of a **root** node with a **label** and **branches**, which is a sequence of **(sub) trees**.

Note: In CS, trees are upside-down!

(More formal definition in CS 70, and even more trees in CS 61B!)



Definition (2 of 2)

Recursive

A tree has a root node and its branches are also trees (subtrees)

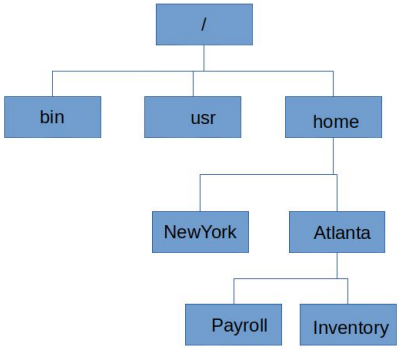
Relative

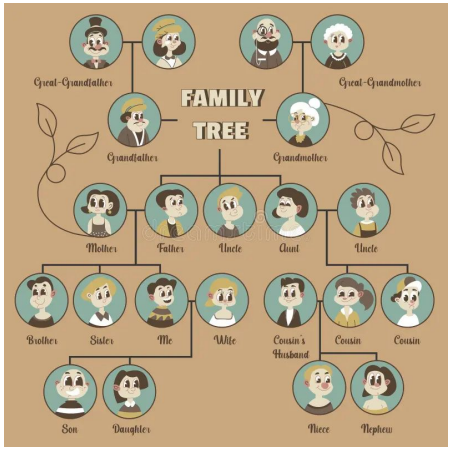
A node has a **parent** and 0 or more **children**

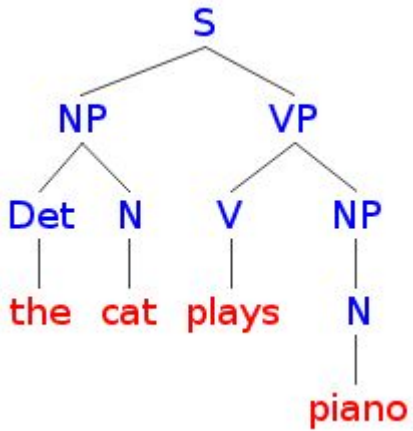
Motivation

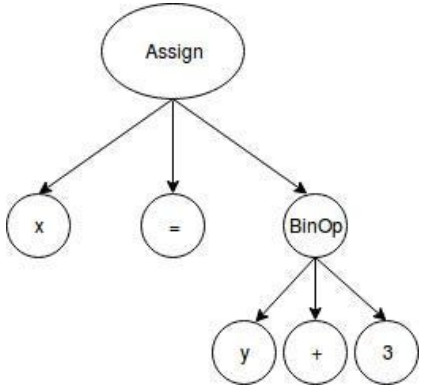
Why do we care about trees? They represent a lot of real-world structures!

- File system
- Hierarchy (political, social, organizational, etc.)
- Family lineages
- Syntax trees (in linguistics (LING 100) and computer science (CS 164))



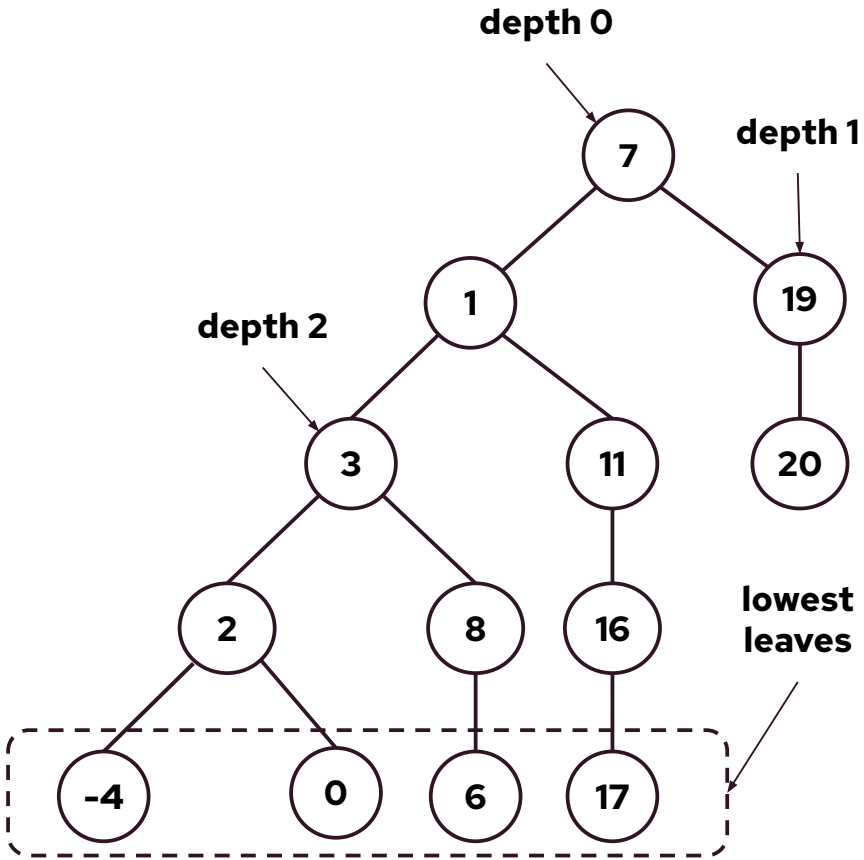






Tree Terminology

- **Depth**: How far away a node is from the root.
  - In other words, the number of edges between the root of the tree to the node.
  - Property of a node
- **Height:** The depth of the lowest leaf.
  - Property of a tree



Tree ADT (1 of 3)

```
def tree(root_label, branches=[]):
    for branch in branches:
        assert is_tree(branch), 'branches must be trees'
    return [root_label] + list(branches)

def label(tree):
    return tree[0]

def branches(tree):
    return tree[1:]
```

Tree ADT (2 of 3)

```
def is_tree(tree):
    if type(tree) != list or len(tree) < 1:
        return False
    for branch in branches(tree):
        if not is_tree(branch):
            return False
    return True

def is_leaf(tree):
    return not branches(tree)
```

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Suppose we have already defined the tree ADT as mentioned in the lecture slides. What would Python display if we evaluated tree(5, [1])?

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Suppose we have already defined the tree ADT as mentioned in the lecture slides. True or false: The following expression is an abstraction barrier violation: tree(1, [tree(2)])

Tree ADT (3 of 3)

```
>>> t = tree(3, [tree(1), tree(2, [tree(1), tree(1)])])
>>> t
[3, [1], [2, [1], [1]]]
>>> label(t)
3
>>> branches(t)
[[1], [2, [1], [1]]]
>>> label(branches(t)[1])
2
>>> is_leaf(t)
False
>>> is_leaf(branches(t)[0])
True
```

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Which of the following tree diagrams corresponds to this expression? tree(5, [tree(1, [tree(0)]), tree(3, [tree(4, [tree(6)])]), tree(2)])

Indentation helps readability!

```
tree(5, [tree(1, [tree(0)]), tree(3, [tree(4, [tree(6)])]), tree(2)])
```

```
tree(5, [tree(1, [tree(0)]),
         tree(3, [tree(4, [tree(6)])]),
         tree(2)])
```

Tree Processing

15 min

- Fibonacci Tree
- Count Leaves

Fibonacci Tree

```
def fib_tree(n):
    """
    Returns a tree representation of the nth Fibonacci number
    """
    if n == 0 or n == 1:
        return tree(n)
    else:
        left, right = fib_tree(n - 2), fib_tree(n - 1)
        fib_n = label(left) + label(right)
        return tree(fib_n, [left, right])
```

code.cs61a.org

1. Go to code.cs61a.org and copy/paste the `fib_tree` definition into a new Python file.
2. Click the green play button in the top right
3. Let's use the `autodraw()` feature to see `fib_tree(5)` in action!

Count Leaves

```
def count_leaves(t):
    """Returns the number of leaves in the tree t"""
    if is_leaf(t):
        return 1
    else:
        branch_counts = [count_leaves(b) for b in branches(t)]
        return sum(branch_counts)
```

5 min break

Practice

(reminder to self to use high contrast theme)

30 min

- Leaves
- Double
- Count Paths

Practice: Leaves

- Implement `leaves`
  - Hint: If you `sum` a list of lists, you will get a list containing the elements of those lists, e.g. `sum([ [1], [2, 3], [4] ], [])` is `[1, 2, 3, 4]`
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  - What didn't?
  - Why?

Practice: Double

- Implement `double`
- Download starter code `09.py` from the course website under Lecture 9
- Run doctests with `python3 -m doctest 09.py`
- 5 min: Try implementing it yourself
- 5 min: Discuss with someone next to you and compare your implementations
  - What worked?
  - What didn't?
  - Why?

Practice: Count Paths

- Implement `count_paths`
  - Hint: Read the doctests carefully!
  - Hint: The tree `t` in the doctests is pictured to the right
- Download starter code `09.py` from the course website under Lecture 9
- Run doctests with `python3 -m doctest 09.py`
- 5 min: Try implementing it yourself
- 5 min: Discuss with someone next to you and compare your implementations
  - What worked?
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