UC Berkeley EECS
Lecturer
Michael Ball

Computational Structures in Data Science

Data Structures: Trees

Learning Objectives

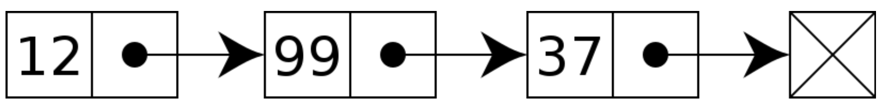
- Trees are a general version of linked lists
- Trees have a value, and are connected to "sub-trees" called branches
- We can often use recursion to process all items in a tree
  - We typically have recursion inside a loop over all the tree's branches
  - This is called "Depth First Search"

Why Use Trees?

- Trees represent lots of natural structures
  - A boss who has employees report to them
  - Courses which belong to departments, and departments which colleges in a University
  - Anything with a hierarchy, really.
    - » A family tree
    - » Biological taxonomies (Kingdom, Phylum....)
    - » Files and Folders

Review: Linked Lists

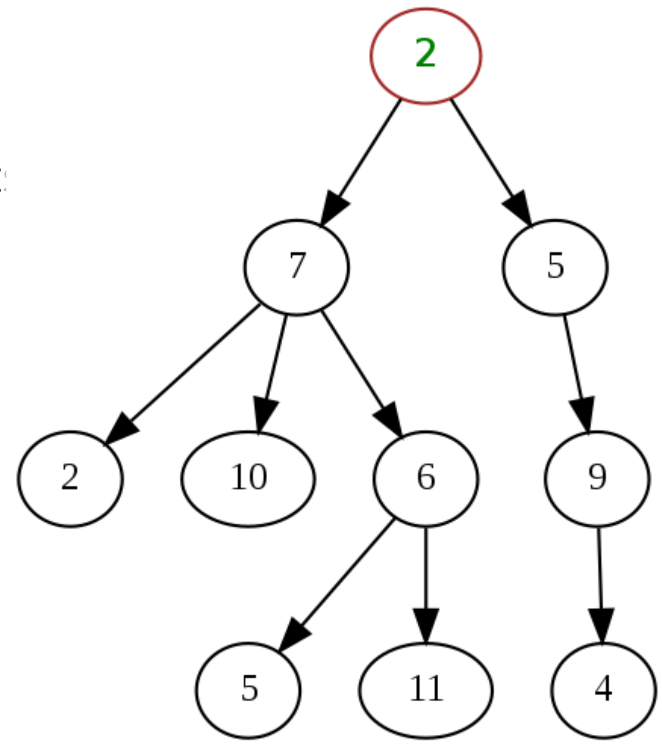
- A Recursive List, sometimes called a ″rlist″
- Linked lists contain other linked lists
- A series of items with two pieces:
  - A value, usually called `"first"`
  - A “pointer” to the `rest` of the items in the list.



- We’ll use a very small Python class “Link” to model this.

What is a tree?

- A recursive data structure
  - Almost like a linked list!
- What if a linked list could have multiple "rest" element:
- We call these "branches".
- **Each branch is also its own Tree.**



Trees are common in Computer Science

- Trees give us really cool approaches for “divide and conquer”
  - Used in every computer to speed up searching for files
  - Used for modeling decision systems in AI programs
  - Used for modelling the kinds of moves in a game.
- Another recursive data structure!
  - We can keep practicing recursion and working with classes
  - Computer sciences really like recursion. ☺
- Trees are a simplified form of a *graph*, a tool which can help us model just about anything.

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Trees: Code Overview
(Go Inspect the ipynb)

```
class Tree:
    def __init__(self, value, branches=()):
        self.value = value
        for branch in branches:
            assert isinstance(branch, Tree)
        self.branches = list(branches)
    def __repr__(self):
        if self.branches:
            branches_str = ', ' + repr(self.branches)
        else:
            branches_str = ''
        return 'Tree({0}{1})'.format(self.value, branches_str)
    def is_leaf(self):
        return not self.branches
    def add_branch(self, tree):
        assert isinstance(tree, Tree), "Each branch of a Tree must be an instance of a 
Tree"
        self.branches.append(tree)
```

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Trees:
Practice With Recursion:
`traverse_recursive`

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Trees:
Counting Each Node

How do we count nodes?

- The "root" or top of the tree is one node.
  - (We assume we can't have a tree of 0 nodes!)
- For each subtree we… Count the nodes!
  - Doesn't this sound like recursion?
- Trick: How do we group the results of recursion?

```python
def count_nodes(t):
    """The number of leaves in tree.

    >>> count_nodes(fib_tree(5))
    8
    """
    if t.is_leaf():
        return 1
    else:
        return 1 + sum(map(count_nodes, t.branches))
```

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Trees:
Practice With Recursion:
`print_tree`

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Trees:
Advanced Topics: Searching
Optional!

Searching Trees: Two Strategies

- The searching we have been doing today is called “Depth First Search”, or DFS.
- Recursion makes the algorithm very nice.
  - First: we deal with our current item, then we get to the branches.
  - We always make a recursive call on the first branch
  - We continue recursing until there are no more branches
  - Then the function executes, and we go back “up” a level and check out the next branch.
  - We sometimes say: “popping up the stack”.
  - The *stack* is the “stack of function calls” the computer uses to keep track of how things work, and you’ll learn about this in CS61B.

Searching a Tree by level: Breadth First Search

- What if I want to check out all the values of my branches before making a recursive call?
- What if we said, you just can't use recursion. (Sometimes, CS instructors do weird things like that...)
- This is used in practice for lots of cool things:
  - Shortest path between two items (more of a graph and not a tree, usually). Google Maps uses it for routing and the algorithms that power the internet use it.