

# Recitation 14



# What's coming up:

- HW4 is due Wednesday, May 6th @ 8:00 pm
  - For HW4 *Order* **64** -> **63** Keys
- The Cumulative Final Exam is Monday, May 11th @6:20-8:20 pm in Eddy 212

# Recitation 14

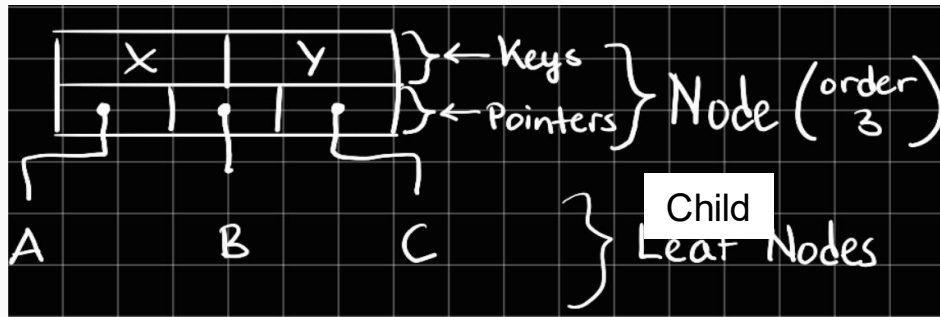
- Basic B Tree operations
  - Lookups, merges, splits, insertions and deletions.
- Terminology:
  - Underflow: when the occupancy of a leaf node falls below its merge threshold.
  - Capacity: The maximum number of values in a node.

# B Trees : (Actually B+ Trees)

- "Order": The maximum number of children a node can have.
  - Nodes in an "Order 25" B-Tree can have 24 keys and 25 children.
  - Also called "Degree"
  - 'Node Capacity' is a property of a node. 'Order' is a property of the whole tree. But they are the same value.
- Underflow: When a node has less than or equal to half its capacity in children.

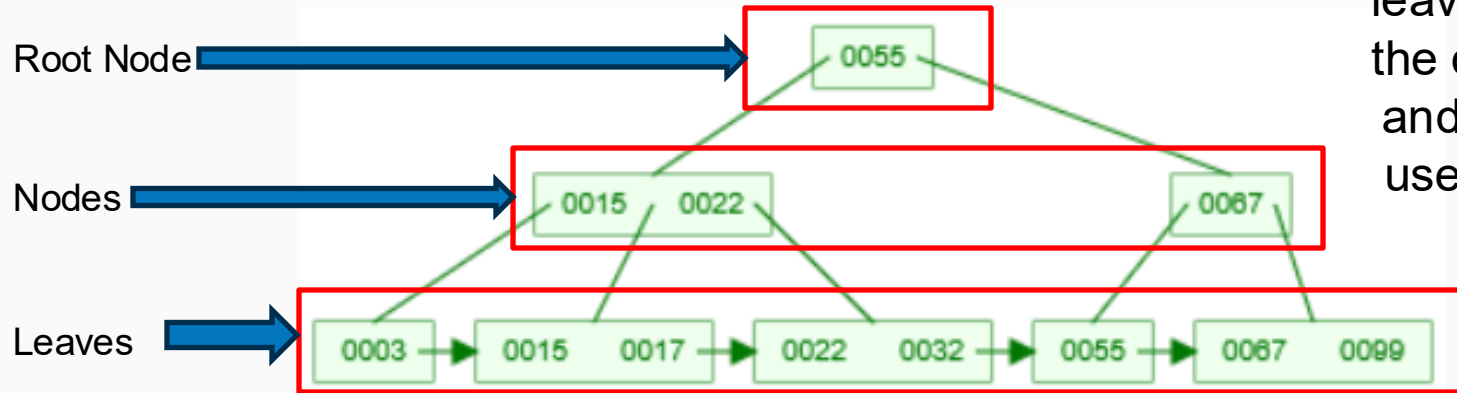
- Anatomy of B-Tree Node:

- $A < x$
- $x \leq B < y$
- $y \leq C$



# B Trees : Diagram

This is an Order 3 tree.



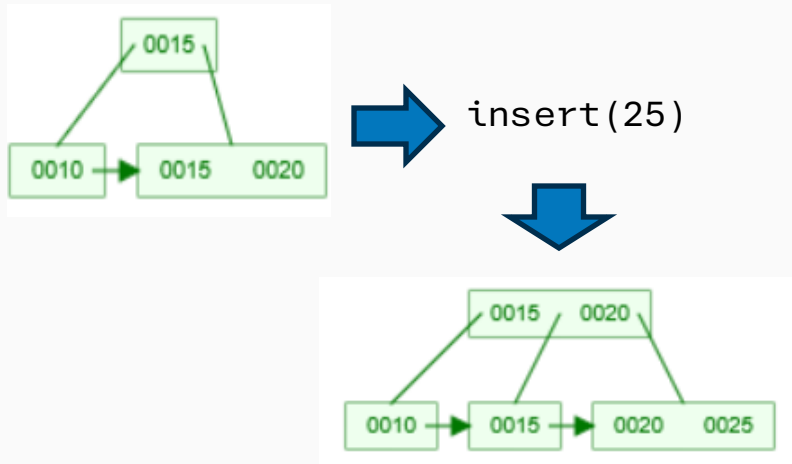
Notice how the leaves contain **ALL** the data in the tree, and the nodes just use them as keys.

# B Trees : Operations

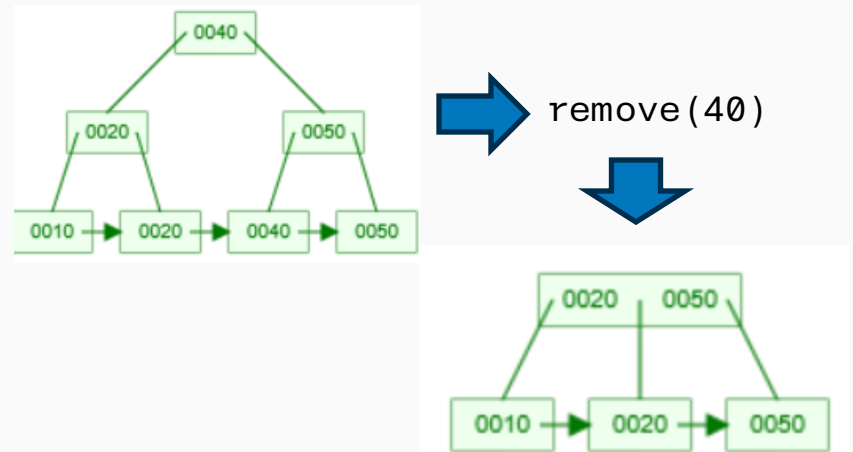
- Basic operations:
  - Lookup
    - Must traverse until you find a leaf
  - Insertion
    - May involve Splits (Triggered by node Overflow)
  - Deletion
    - May involve Merges (Triggered by node Underflow)

# B Trees: Underflow & Overflow

- Overflow: when a node's capacity is reached, it must split into multiple smaller nodes



- Underflow: when a node's occupancy falls below its underflow threshold (Usually half its capacity)



# HW4

- HW4 uses Order 64 -> 63 keys
- Splits:
  - Typically at median
  - Capacity is odd, therefore split at the middle index
    - Choose equal distribution left vs. Right nodes
- Merge:
  - Can occur at a threshold to prevent underflow
    - E.g. less than half occupancy
- Primary HW4 concern:
  - Working tree structures

# HW4

- Test your own code
  - Step by step test your code before reading the 10,000 numbers from the provided data.txt
  - BTree visualization tool: <https://www.cs.usfca.edu/~galles/visualization/BPlusTree.html>
  - BST visualization tool: <https://www.cs.usfca.edu/~galles/visualization/BST.html>
- It's insufficient to just compare the example output to your output
  - Example output only prints 10 random numbers... which is not the entire picture

# Explore on your own

- Use the website here:
  - <https://www.cs.usfca.edu/~galles/visualization/BPlusTree.html>
- Try and answer the following questions:
  - What happens when a leaf node splits?
  - What happens when an internal node splits? Is it different
  - What happens when leaf nodes merge?
  - What happens when internal nodes merge?
  - Can a B+ Tree have keys in internal nodes that don't exist as data in the leaves?
- Try completing the worksheet in canvas

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- Complete the worksheet located on canvas.