Multi-way Search Trees

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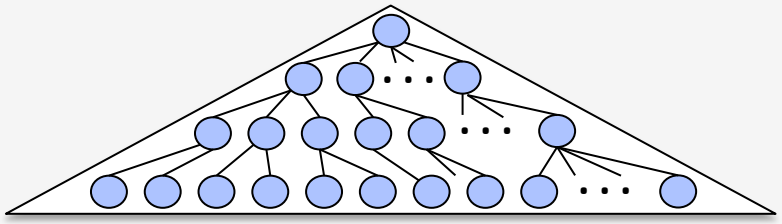
Multi-way search trees

A multi-way search tree (an **M-way tree**) is a tree of order M > 2 in which the search property (total order) holds on every node and in which all leaves are at the same depth.

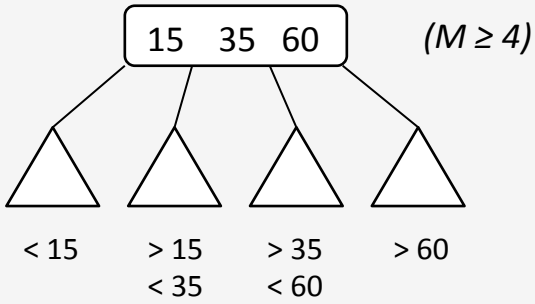


In an M-way tree:

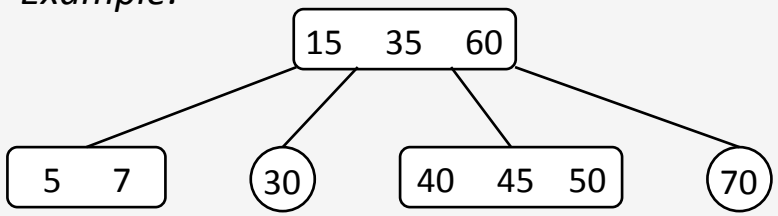
Each node holds between 1 and M-1 values in sorted order.

A non-leaf node with K values has K+1 non-empty subtrees that are M-way search trees.

The i-th subtree of a node that holds values $[v_0..v_k]$ $(0 \le i \le K)$ can only store values v such that $v_{i-1} < v < v_i$.



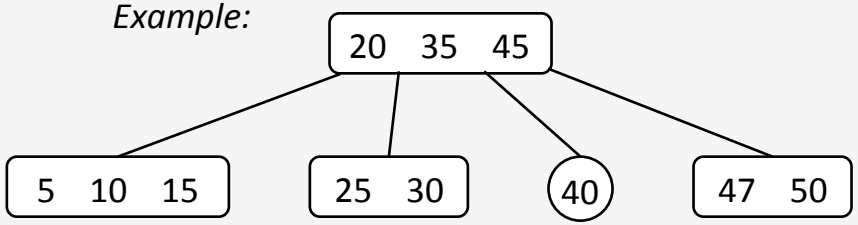
Example:



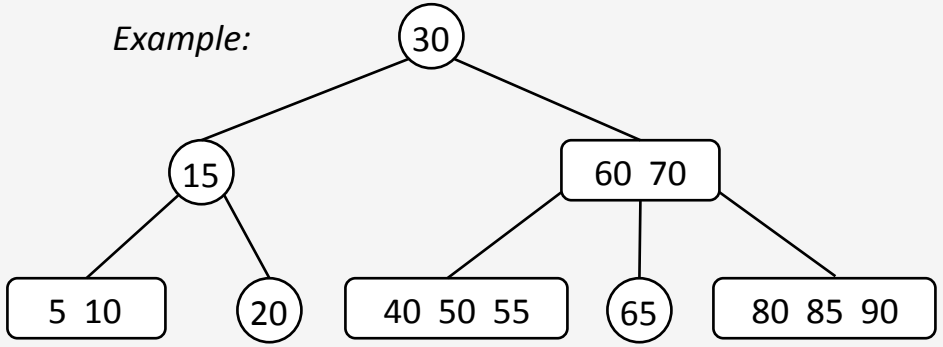
2-4 Trees

A 2-4 tree is a 4-way search tree where each non-leaf node must have at least two non-empty subtrees.

Example:



Example:



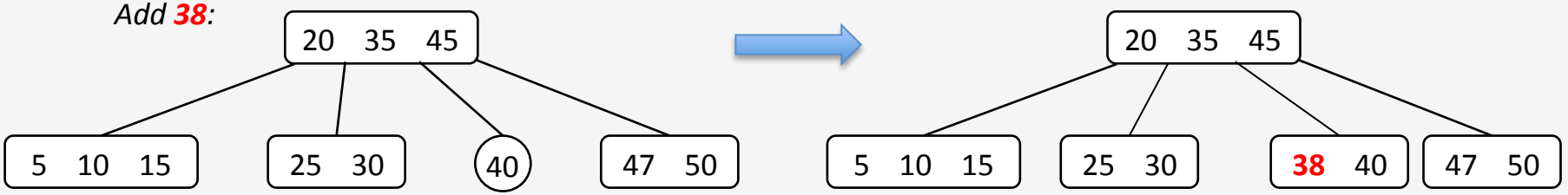
2-4 Trees – adding values

To add a new value, use the total order to find the **leaf** that should hold this value.

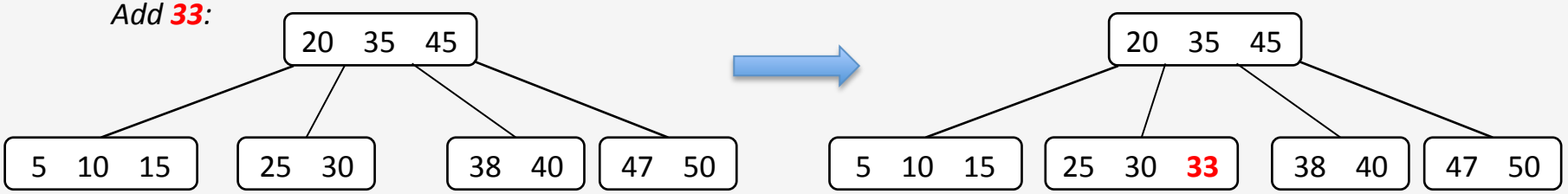
New values are always added in the context of an existing leaf node.

*New values in a BST went into a **new leaf** in a currently empty subtree.*

*Add **38**:*

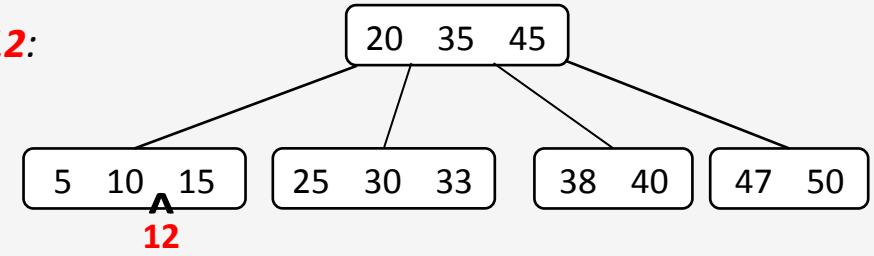


*Add **33**:*



2-4 Trees – growing taller

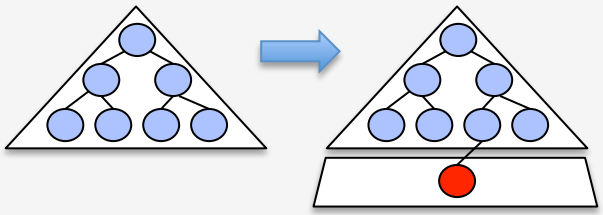
*Add **12**:*



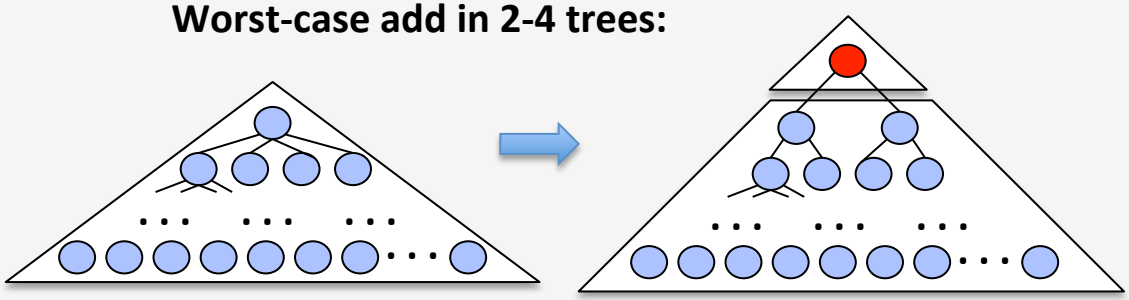
M-way search trees grow taller in a different way than BSTs.

A node in a 2-4 tree can store up to 3 values, so this leaf is **full**.

Worst-case add in balanced BSTs:



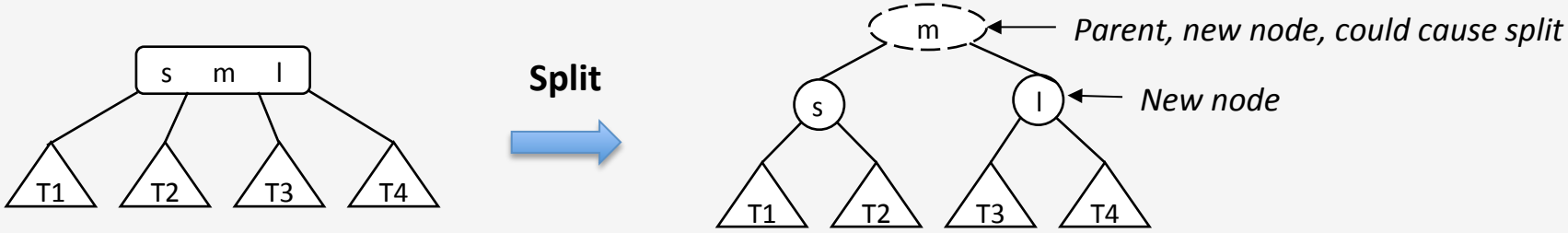
Worst-case add in 2-4 trees:



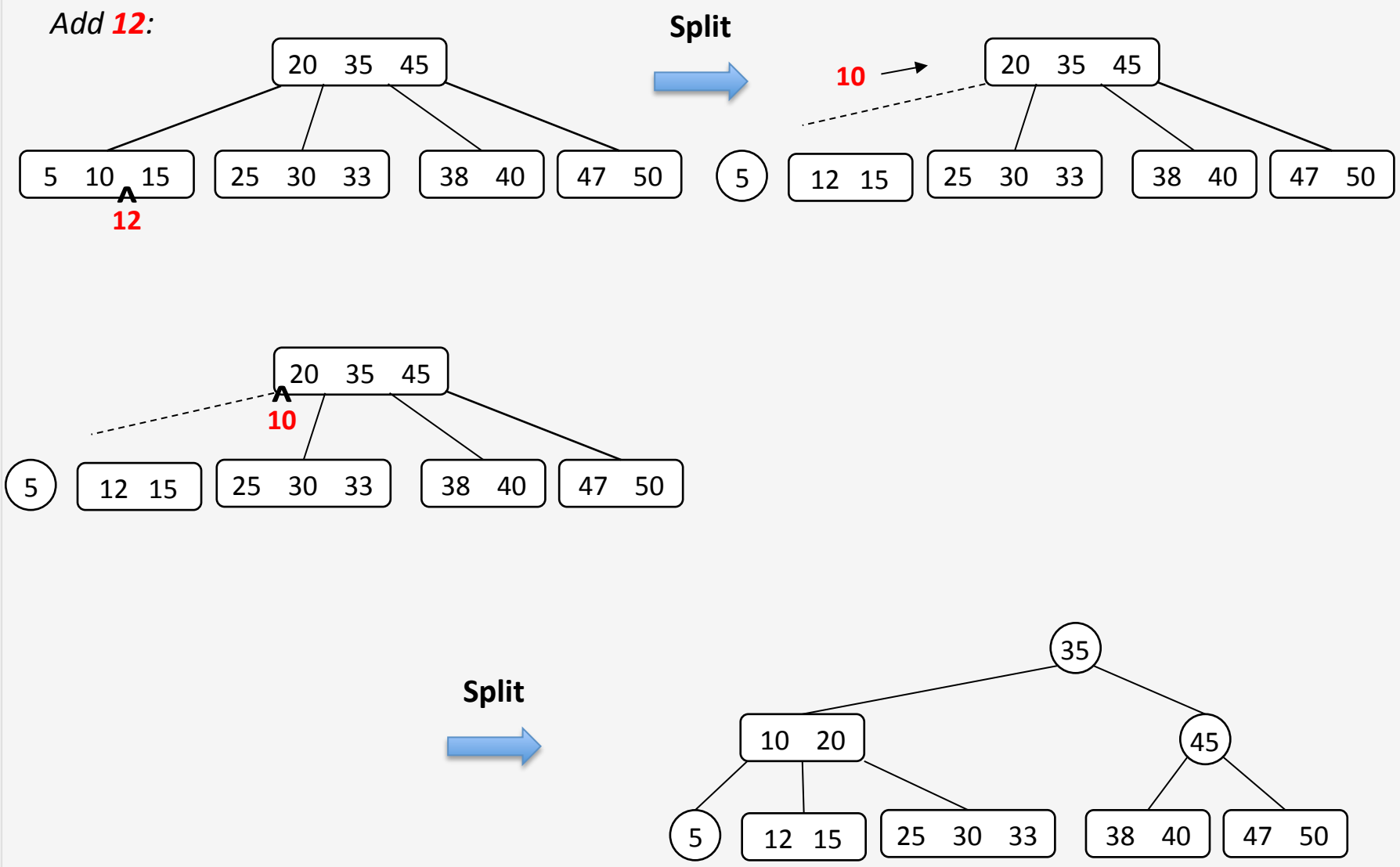
All leaves in a 2-4 tree have to be at the same level.

The tree grows "up" by adding a new root rather than down by adding a new (lower) leaf.

When a 2-4 node is full but it needs to store another value, we perform a **split**.



2-4 Trees – growing taller



Growing a 2-4 Tree

Insert: 10, 85, 15, 70, 20, 60, 30, 50, 65, 80, 90, 40, 5, 55