#### **AVL Tree II**

- Time complexity
- Reconstruct AVL tree from BST in O(n)
  - rebalanceTree()
  - Use inorder() either keys or nodes
- growN(), trimN()
  - use rebalanceTree() instead of rebalance()

Algorithm	BST		AVL	
	Worst	Average	Worst	Average
Search	O(n)	O(log n)	O(log n)	O(log n)
Insertion	O(n)	O(log n)	O(log n)	O(log n)
Deletion	O(n)	O(log n)	O(log n)	O(log n)
grow N, trim N	O(n^2)	O(n log n)	O(n log n)	O(n log n)
rebalance()			O(log n)	O(log n)
rebalance N			O(n log n)	O(n log n)

```
// inserts a key into the AVL tree and rebalance it.
tree growAVL(tree node, int key) {
  if (node == nullptr) return new TreeNode(key);

  // your code here
  return rebalance(node); // O(log n)
}
```

```
tree rebalanceTree(tree node) { // may need a better solution here
  if (node == nullptr) return nullptr;

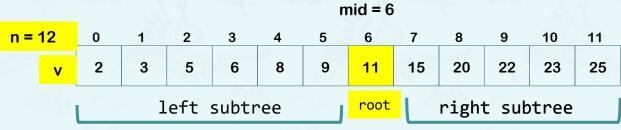
while (!isAVL(node)) // O(n) ~ O(n^2)
  node = _rebalanceTree(node); // n log(n)

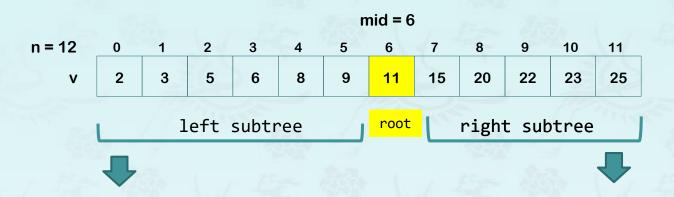
return node;
}
```

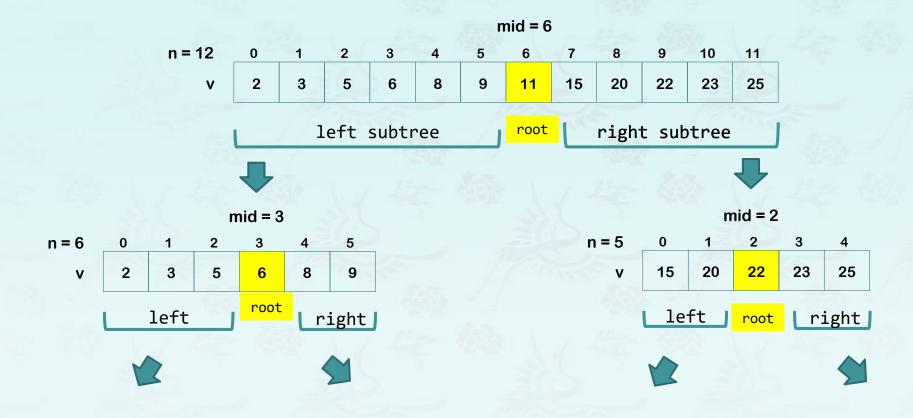
```
// inserts N numbers of keys in the tree(AVL or BST)
// If it is empty, the key values to add ranges from 0 to N-1.
// If it is not empty, it ranges from (max+1) to (max+1 + N).
tree growN(tree root, int N, bool AVLtree) { // recode tree.cpp
  int start = empty(root) ? 0 : value(maximum(root)) + 1;
  int* arr = new (nothrow) int[N];
  assert(arr != nullptr);
  randomN(arr, N, start);
  for (int i = 0; i < N; i++) root = grow(root, arr[i]);
  if (AVLtree) root = rebalanceTree(root);
  delete[] arr;
                                        Use BST grow() instead of growAVL()
  return root;
                                        since AVL is a BST and
                                        we can avoid calling rebalance() N times.
```

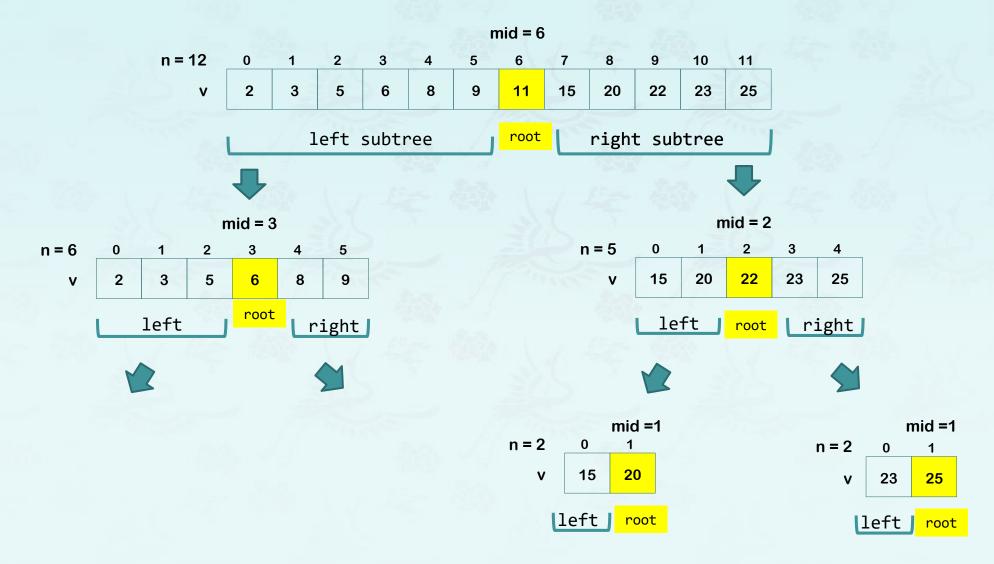
```
// removes randomly N numbers of nodes in the tree(AVL or BST).
// It gets N node keys from the tree, trim one by one randomly.
tree trimN(tree root, int N, bool AVLtree) { // recode tree.cpp
  vector<int> vec;
  inorder(root, vec);
  shuffle(vec.data(), vec.size());
  int tsize = size(root);
  assert(vec.size() == tsize); // make sure we've got them all
  int count = N > tsize ? tsize : N;
  for (int i = 0; i < N; i++) root = trim(root, arr[i]);
  if (AVLtree) root = rebalanceTree(root);
  delete[] arr;
                                        Use BST trim() instead of trimAVL()
  return root;
                                        since AVL is a BST and
                                        we can avoid calling rebalance() N times.
```

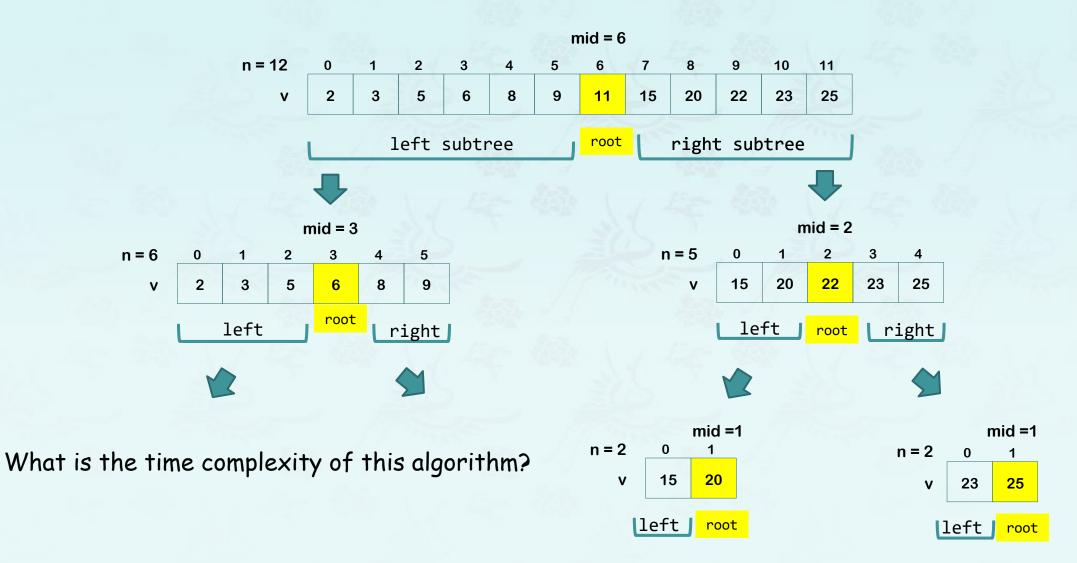
```
// rebuilds an AVL tree with a list of keys sorted.
// v - an array of keys sorted, n - the array size
tree buildAVL(int* v, int n) {
  if (n <= 0) return nullptr;</pre>
  int mid = n / 2;
  // create a root node
 // recursive buildAVL() calls for left & right
  // your code here
  return root;
```

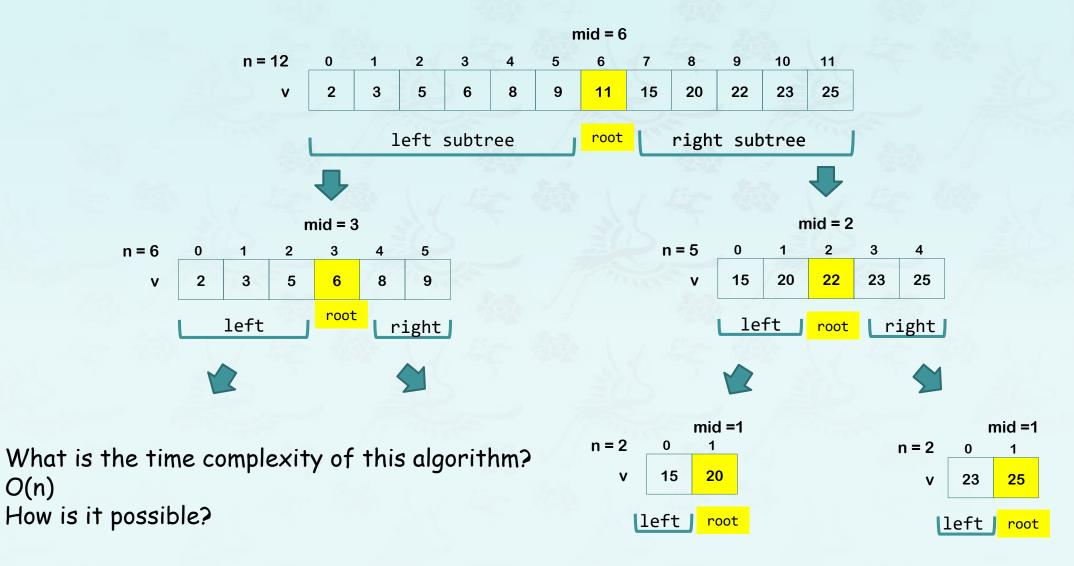








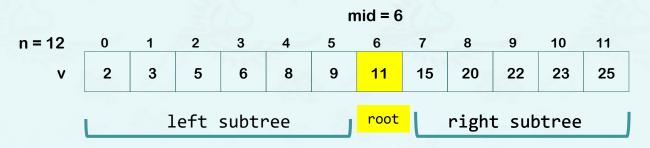




O(n)

#### RebalanceTree() reconstructs AVL from BST in O(n)

```
// reconstructs a new AVL tree from BST in O(n).
tree rebalanceTree(tree root) {
  if (root == nullptr) return nullptr;
  // you may use inorder() to get an array of keys or nodes
  // if you use an array of nodes, you just reconstructs AVL tree using nodes.
  // if you use an array of keys, the root should be cleared (or deallocated)
                                       // O(n)
 // your code here
  return buildAVL(v.data(), v.size()); // O(n)
```



### RebalanceTree() reconstructs AVL from BST in O(n)