

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()`

Time Complexity in big O notation:

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			$O(n \log n)$	$O(n \log n)$

Time Complexity in big O notation:

```
// 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;
}
```

Time Complexity in big O notation:

```
// 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;
    return root;
}
```

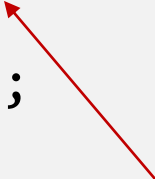
Use BST grow() instead of growAVL() since AVL is a BST and we can avoid calling rebalance() N times.

Time Complexity in big O notation:

```
// 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, vec[i]);

    if (AVLtree) root = rebalanceTree(root);
    return root;
}
```



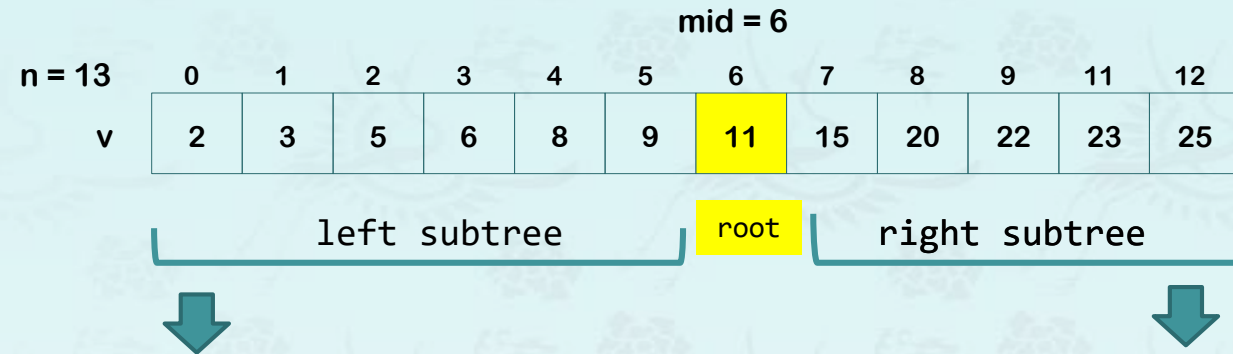
Use BST trim() instead of trimAVL()
since AVL is a BST and
we can avoid calling rebalance() N times.

Building AVL tree from BST in $O(n)$

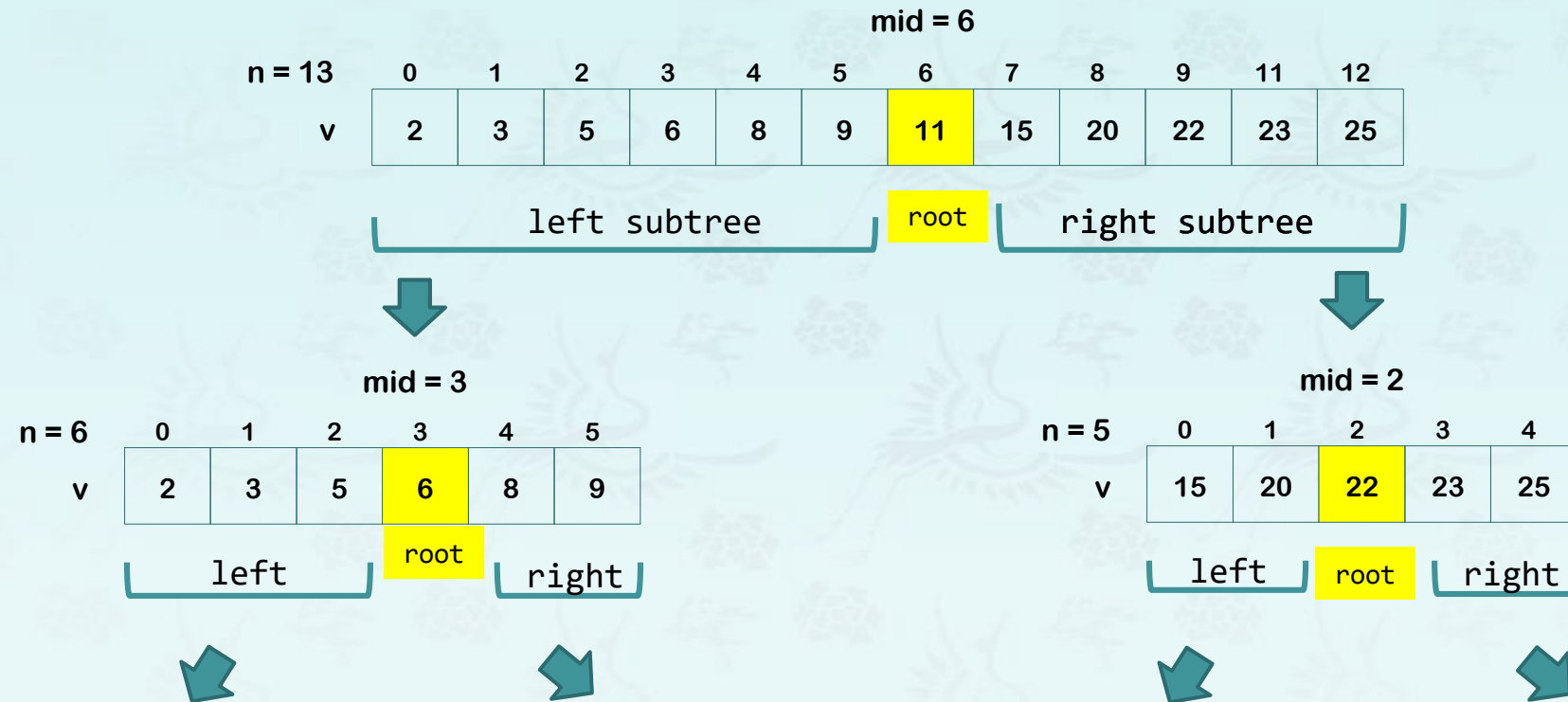
```
// rebuilds an AVL tree with a list of keys sorted.  
// v - an array of keys sorted, n - the array size  
tree buildAVL(int* v, int n) {  
    if (n <= 0) return nullptr;  
    int mid = n / 2;  
    // create a root node  
  
    // recursive buildAVL() calls for left & right  
  
    // your code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



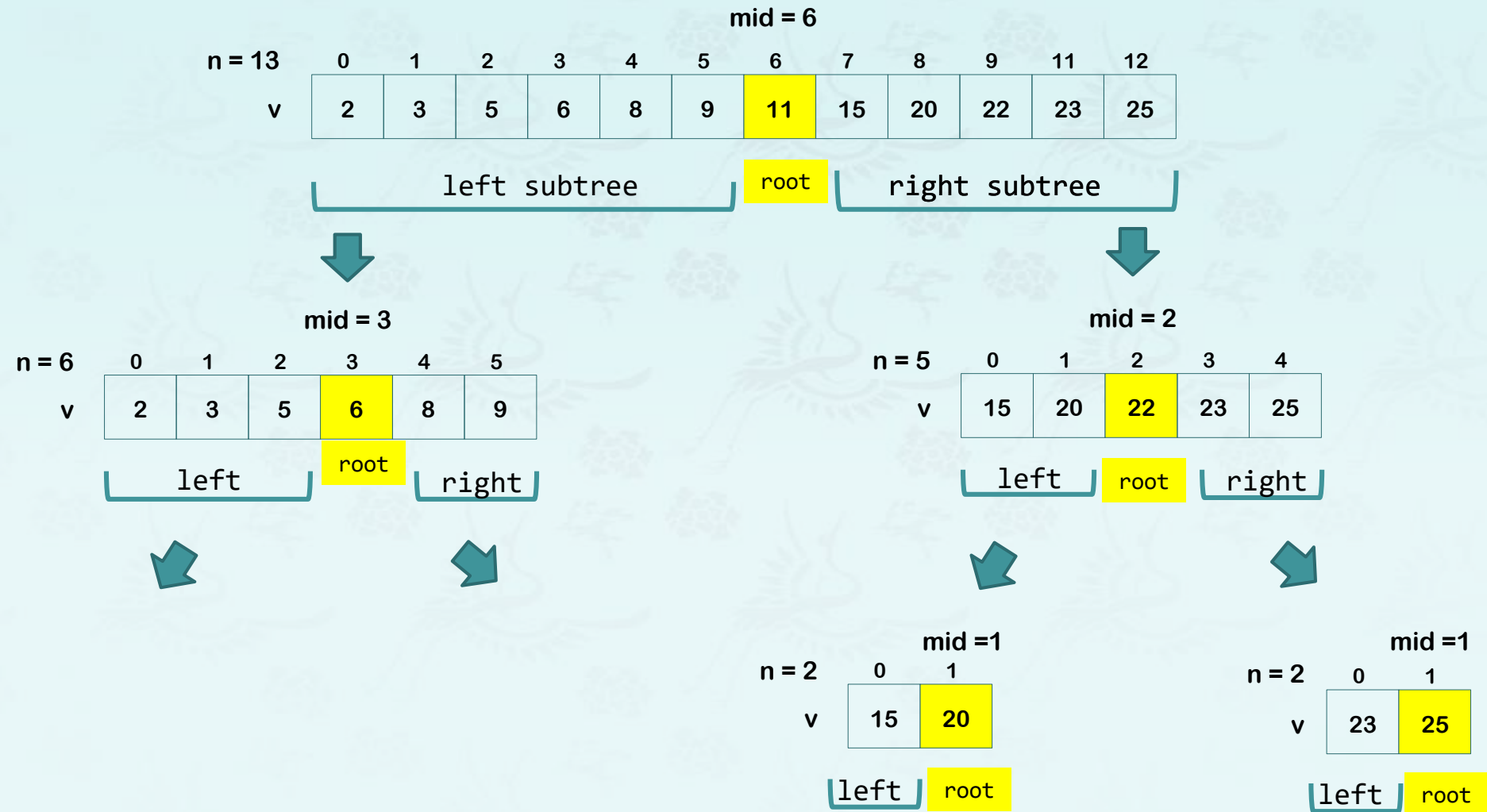
Building AVL tree from BST in $O(n)$



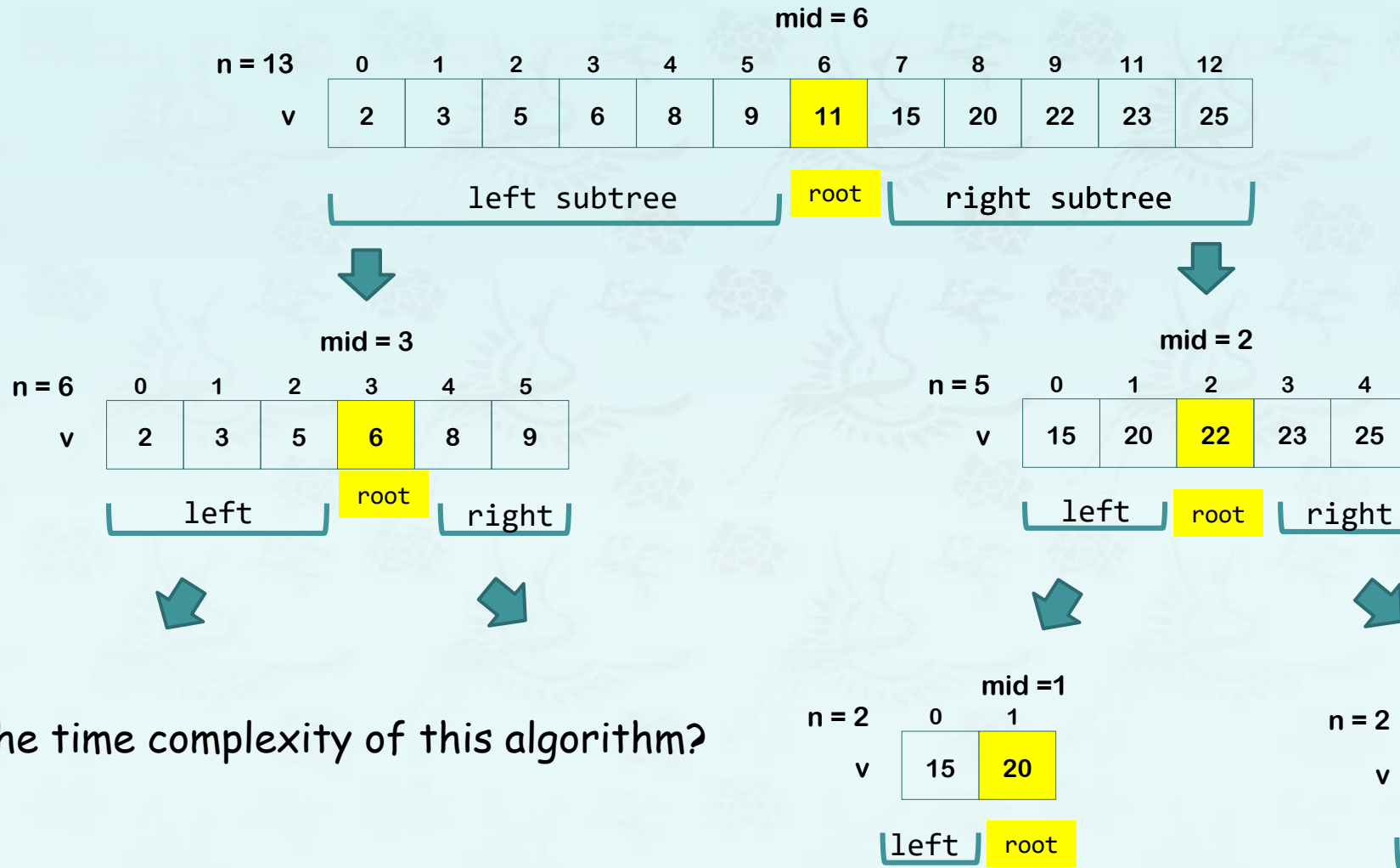
Building AVL tree from BST in $O(n)$



Building AVL tree from BST in $O(n)$

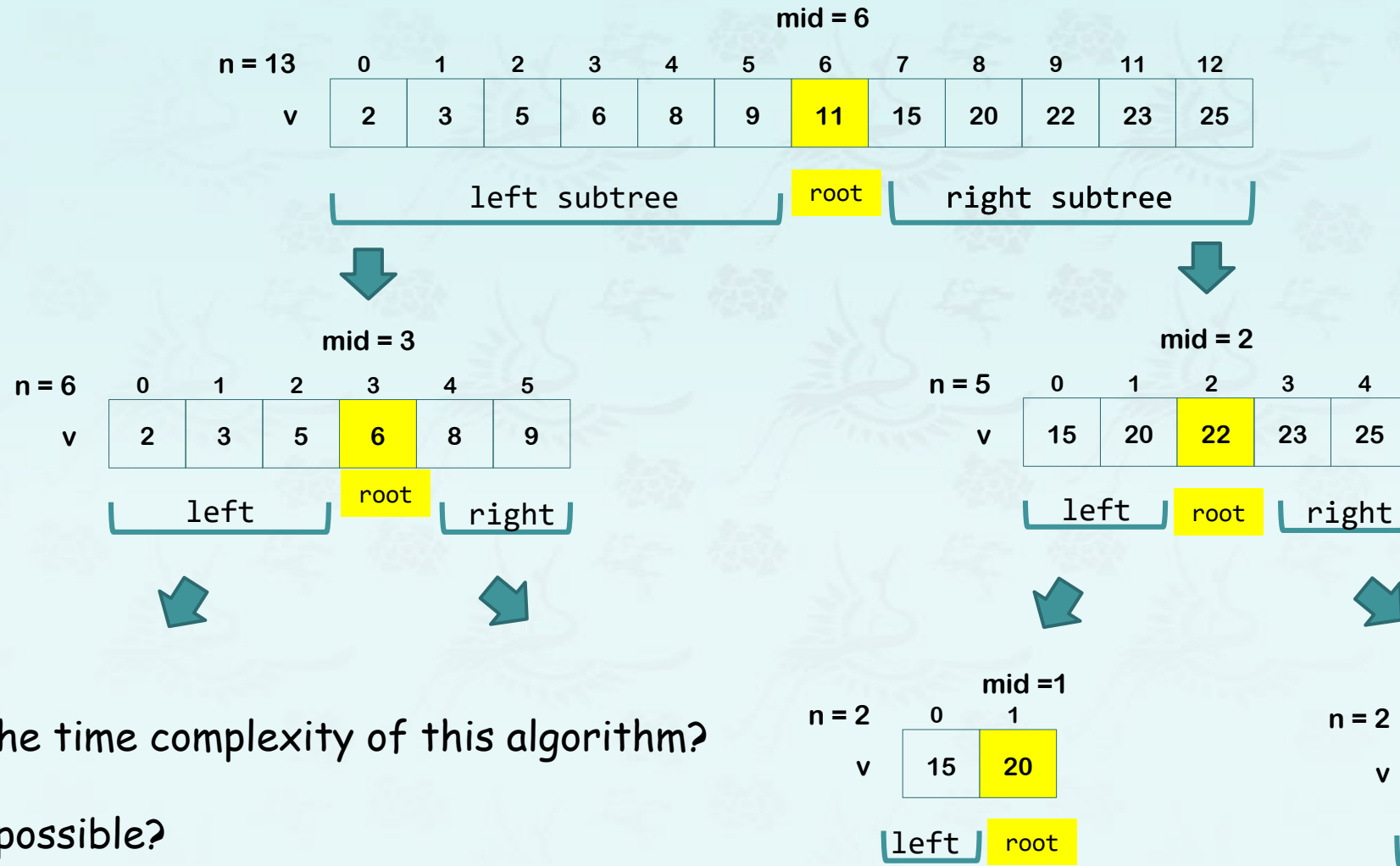


Building AVL tree from BST in $O(n)$



What is the time complexity of this algorithm?

Building AVL tree from BST in $O(n)$



What is the time complexity of this algorithm?

$O(n)$

How is it possible?

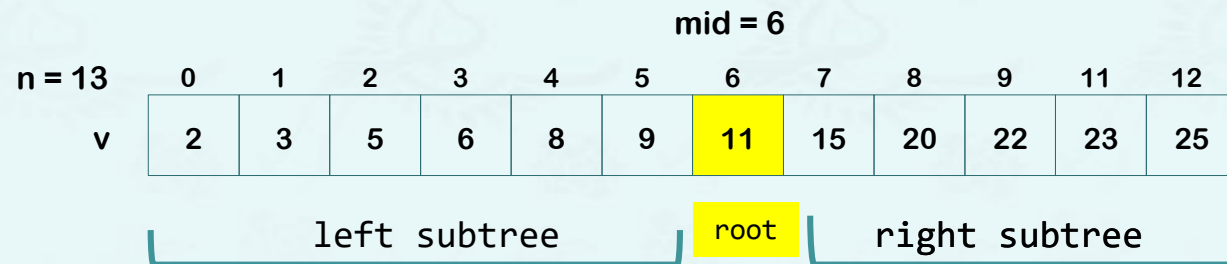
RebalanceTree() reconstructs AVL from BST in $O(n)$

```
// 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)

    // your code here                                //  $O(n)$ 

    return buildAVL(v.data(), v.size()); //  $O(n)$ 
}
```



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

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

    while (!isAVL(node))           //  $O(n) \sim O(n \log n)$ 
        node = _rebalanceTree(node); //  $\log(n)$ 

    return node;
} // this algorithm needs to be improved.
```

invokes rebalance() recursively
for left and right subtrees