DTS203TC
Design and Analysis of Algorithms

Lecture 8: Data Structures

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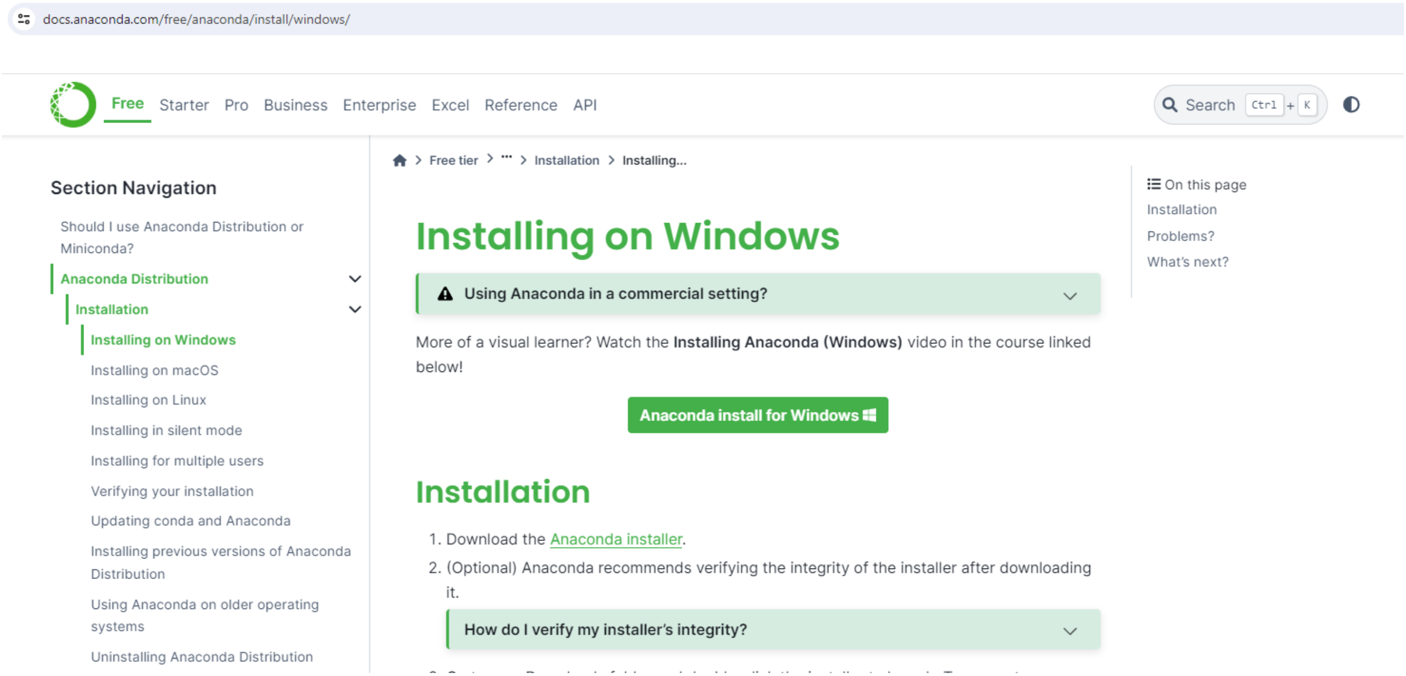
Wednesday/Thursday 14:00-16:00

Learning outcomes

- Installation tips
- Linked List
- Binary Search Tree
- AVL Tree

Installation

- Install Anaconda: https://docs.anaconda.com/free/anaconda/install/windows/



Installation

- Install Jupyter notebook: https://jupyter.org/install

Jupyter Notebook

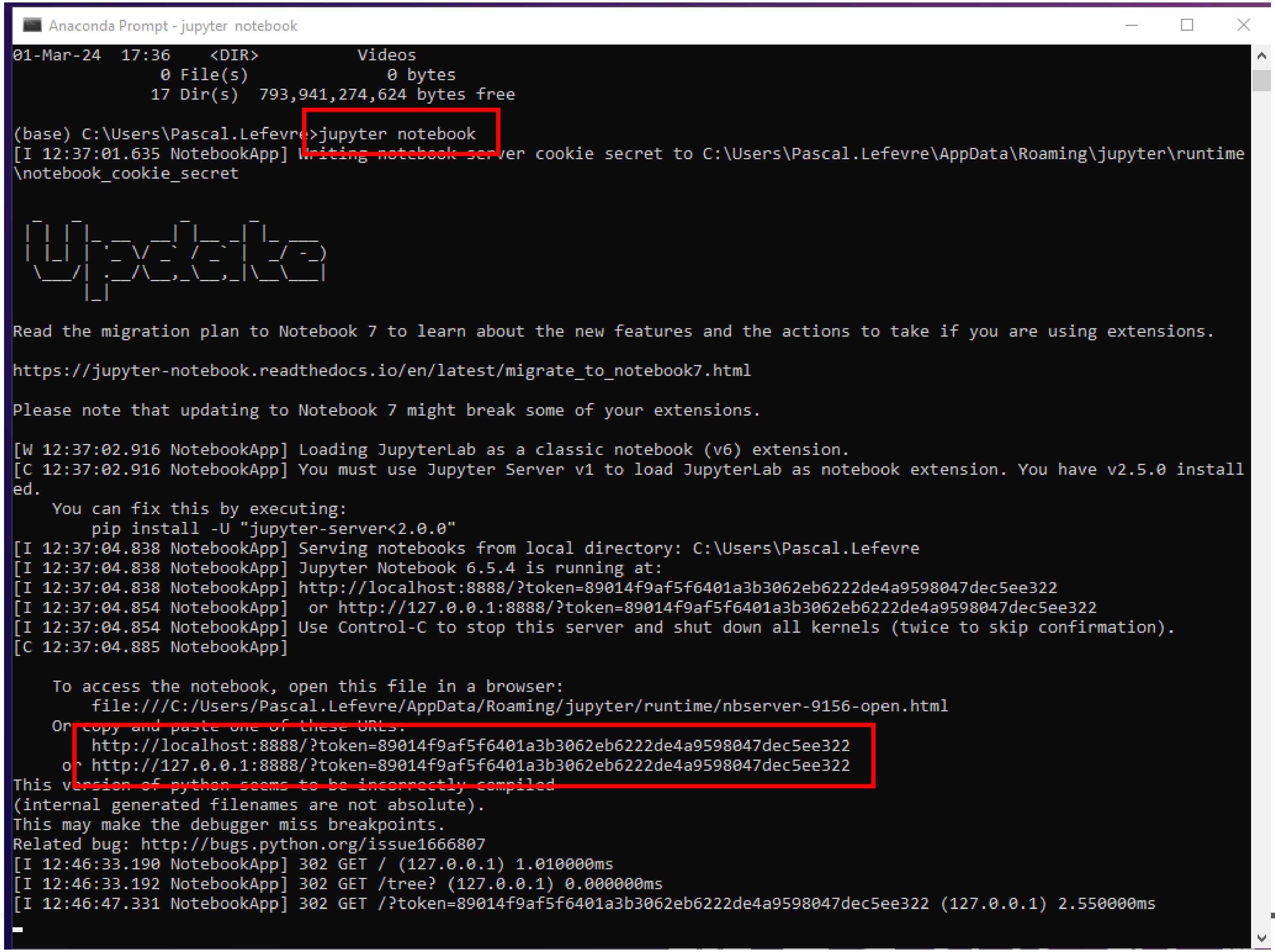
Install the classic Jupyter Notebook with:

```
pip install notebook
```

To run the notebook:

```
jupyter notebook
```

Installation



Linked List

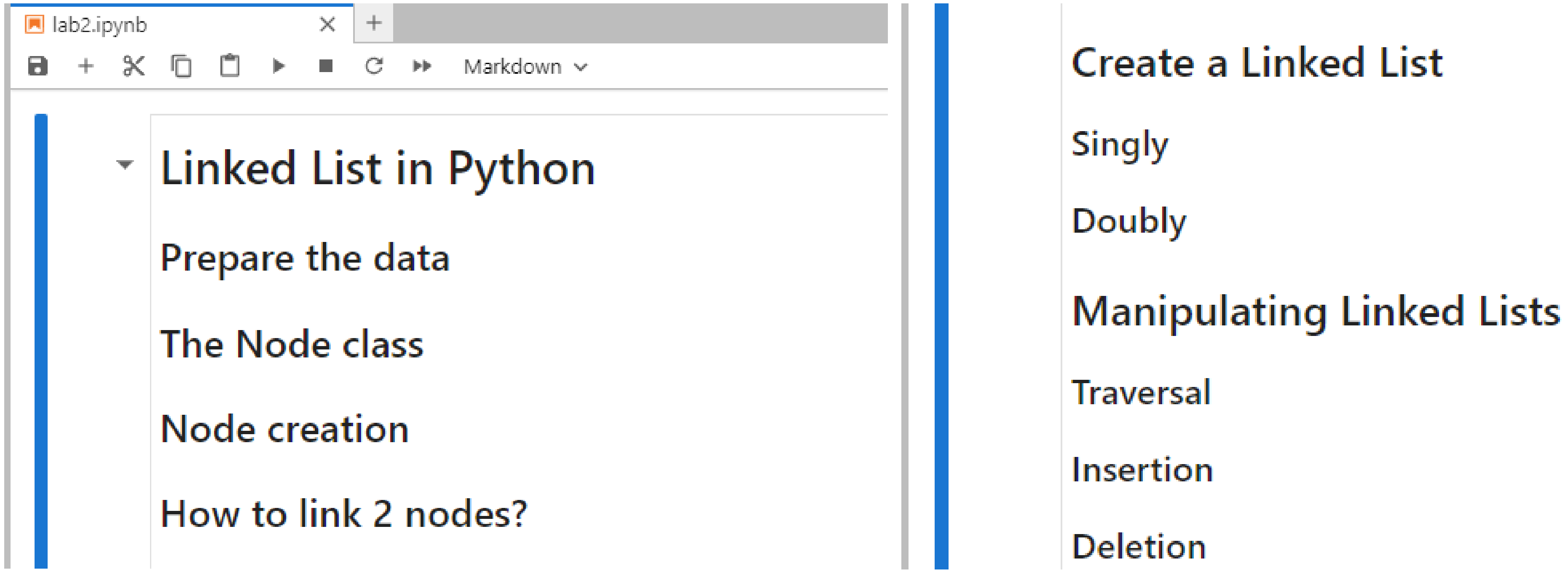
Definition – Linked List

- Linear data structure + series of nodes
- Each node has a value
- Traversal: using pointers
- Types: singly, doubly, circular

Operations – Linked List

- Traversal
- Search
- Insertion, deletion

Implementation – Linked List



See notebook lab2.ipynb

Notebook – Linked List

- See: Lecture 8 - Data Structures - Notebook.ipynb

Notebook – Linked List

Linked List in Python

The Node class

In [1]:
```
class Node:
    def __init__(self, data):
        self.data = data
        self.prev = None
        self.next = None

    def __str__(self):
        return f'Node({self.data})'
```

Node creation

In [2]:
```
# a variable node contains the value 10
node = Node(10)
```

In [3]:
```
# display value inside the node
print(node.value)  # gives an error, why?s
```

```
---------------------------------------------------------------------------
AttributeError                            Traceback (most recent call last)
Cell In[3], line 2
      1 # display value inside the node
----> 2 print(node.value)

AttributeError: 'Node' object has no attribute 'value'
```

In [ ]:
```
# display the pointers
print(node.prev, node.next)
# the node is not connected to others nodes
```

Notebook – Linked List

How to link 2 nodes?

In [ ]:
```
# declare two nodes
n1 = Node(10)
n2 = Node(20)

n1.next = n2
```

In [ ]:
```
print(n1.next)
```

In [ ]:
```
# link 2 nodes with 2 pointers
# how?

n2.prev = n1

prnt(n2.prev)
```

Create a Linked List

In [ ]:
```
# our Data
number_list = [10, 20, 4, 2]

# define the nodes
node_list = [Node(10), Node(20), Node(4), Node(2)]

# define using the list called number_list
node_list = [Node(data) for data in number_list]
```

Singly

In [ ]:
```
node_list[0].next = node_list[1]
node_list[1].next = node_list[2]
node_list[2].next = node_list[3]

# we start with the head
head = node_list[0]

print(head)
print(head.next)
print(head.next.next)
print(head.next.next.next)
print(head.next.next.next.next)
```

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Notebook – Linked List

Doubly

In [ ]:
```
# use the Node.prev method to link the nodes in the reverse order

tail = node_list[3]
tail.prev = node_list[2]
node_list[2].prev = node_list[1]
# and so on
```

Manipulating Linked Lists

Traversal

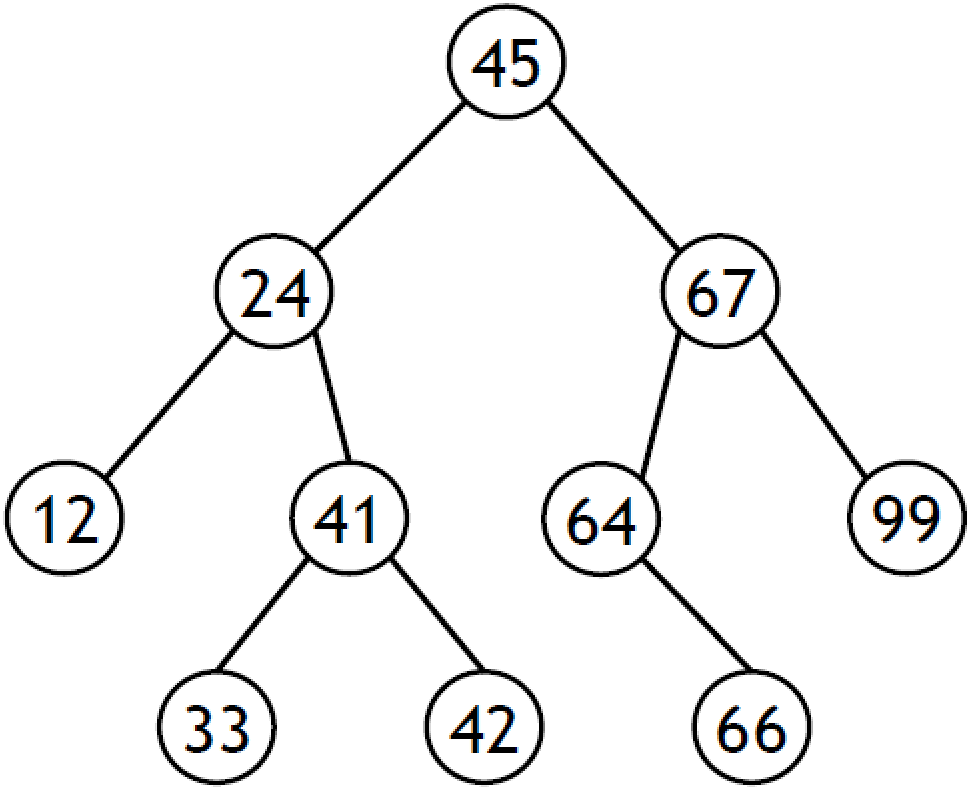
In [ ]:
```
# traversal of a linked list using a loop
head = node_list[0]

while head is not None:
    print(head)
    head = head.next
```

In [ ]:
```
# how about the search?

value = 4

head = node_list[0]

while head is not None:
    print(head)
    # search here
    # if value .......
    #     ....
    head = head.next
```

Binary Search Tree

Definition – Binary Search Tree

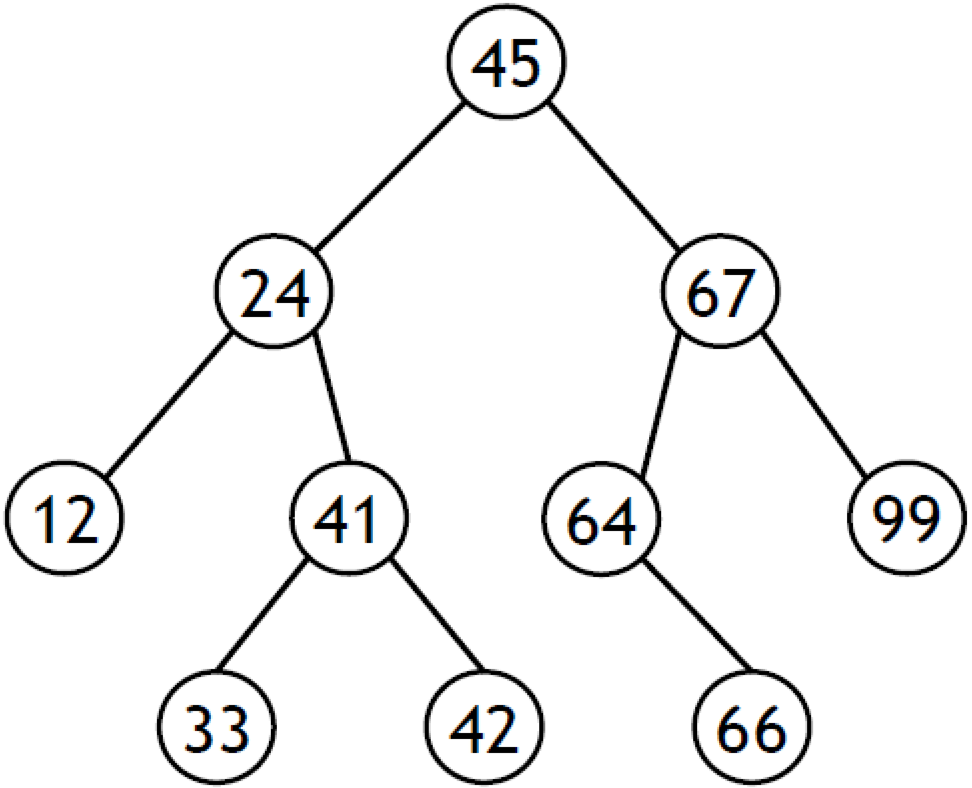
- Binary tree
- Each node has a key
- Two children at most
  - Left child
  - Right child



Node.left.key <= node.key <= node.right.key

Operations – Binary Search Tree

- Traversal
- Search
- Insertion, deletion
- Find the Minimum and Maximum



Notebook – Binary Search Tree

- See: Lecture 8 - Data Structures - Notebook.ipynb

Notebook – Binary Search Tree

The Node class for Linked List

In [ ]:
```
class NodeLL:
    def __init__(self, data):
        self.data = data
        self.prev = None
        self.next = None

    def __str__(self):
        return f'NodeLL({self.data})'
```

The Node class for BST

In [13]:
```
class Node:
    def __init__(self, key):
        self.left = None
        self.right = None
        self.key = key

    def __str__(self):
        return f'Node({self.key})'
```

Data - Create a BST

In [14]:
```
# create 3 nodes and display them
a, b, c = 2, 3, 1

n1 = Node(a)
n2 = Node(b)
n3 = Node(c)

print(n1)
print(n2)
print(n3)
```

Notebook – Binary Search Tree

Link the nodes to get a BST

In [15]:
```
# we start with a, then b and finally c
root = n1
root.left = n3
root.right = n2

# print the nodes from the root
print(root)
print(root.left, root.right)
```

```
Node(2)
Node(1) Node(3)
```

Insert a key

In [16]:
```
# let's add the key 0
# first, create a node

new_node = Node(0)

# then add it to the BST, but how?
root.left.left = new_node

# because 0 < 1, so we insert at the left of Node(1)
```

In [17]:
```
# let's print the new_node
print(root.left.left)
```

```
Node(0)
```

In [18]:
```
# let's add another node, say a key 10
another_node = Node(10)

root.right.right = another_node
print(root.right.right)
```

Notebook – Binary Search Tree

Searching inside a BST

In [7]:
```
# Search(x,k)
#     if x == NULL or k == x.key
#         return x
#     if k < x.key
#         return Search(x.left,k)
#     else
#         return Search(x.right,k)
```

In [19]:
```
# x is the root of BST
# k is the key vaue to search

def search(x, k):
    if x == None or k == x.key:
        return x
    if k < x.key:
        return search(x.left, k)
    else:
        return search(x.right, k)
```

In [26]:
```
print(root)

# can we find element -1?
element_found = search(root, -1)

print(element_found)  # return None, so we cannot find -1
```

```
Node(2)
None
```

In [ ]:
```
# Can we find 10?
element_found = search(root, 10)

print(element_found)  # return 10, so yes we found the element
```

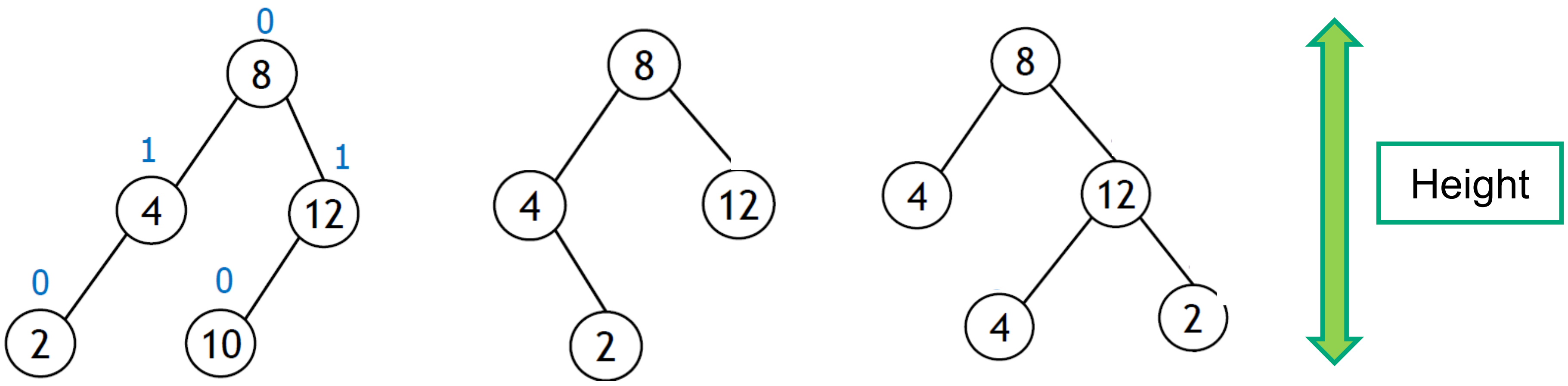
AVL Tree

Definition – AVL Tree

- BST
- Height-balanced

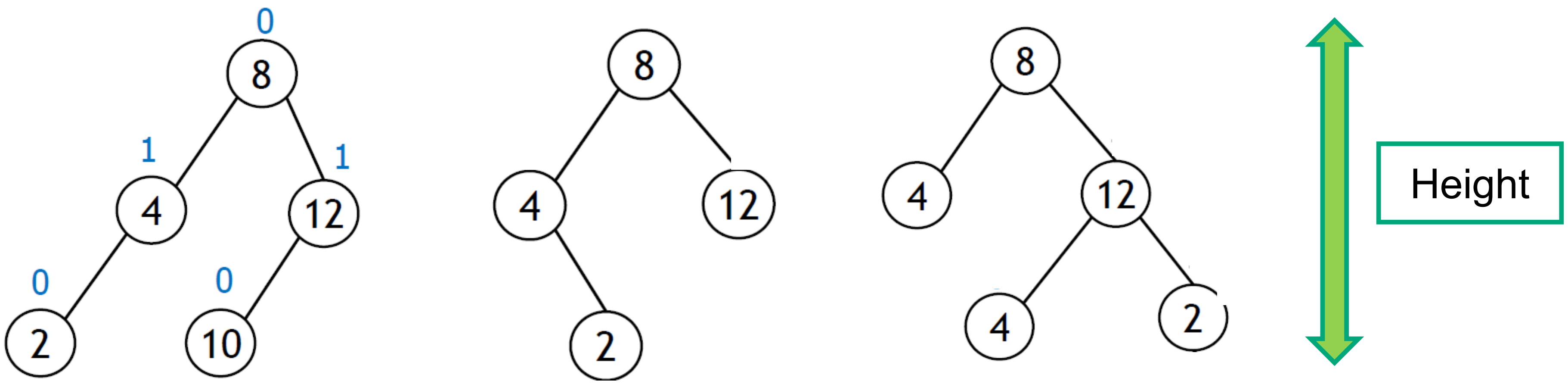
Balance factor of a node = {-1, 0, 1}

Balance factor = height of left subtree – height of right subtree



Definition – AVL Tree

- Rotation
- Insertion
- Deletion



Notebook – AVL Tree

- See: Lecture 8 - Data Structures - Notebook.ipynb

Notebook – AVL Tree

AVL Tree

In [28]:
```
class Node:
    def __init__(self, key):
        self.key = key
        self.left = None
        self.right = None
        self.height = 1
```

In [29]:
```
n1 = Node(10)
n2 = Node(20)
n3 = Node(30)
```

In [ ]:
```
root = Node(20)
```

In [ ]:
```
# create a BST
```

In [ ]:
```
# create an AVL tree
# it needs to be balanced
# we need to adjust the height
# calculate the balance factor for each node
# example
# 8
# 4 12
# 2 null 10 null
```

Notebook – AVL Tree

In [ ]:
```
# perform a single rotation
# initially: 10, 20
# insert 30 in this BST (the tree becomes imbalanced)
# perform a Left Rotation

root = Node(30)
root.left = Node(10)

# insert 30
# perform a search for 30, if 30 is not in this AVL tree, we insert at the suitable position in the BST
# reuse the previous search algorithm for BST

# perform Left Rotation
# how to do it manually?
```

In [ ]:
```
# perform a Right Rotation
```

In [ ]:
```
# perform a Double Rotation: Right-Left Rotation
# it is 1 rotation in 2 steps
```

Any questions?