[redacted] (/)

Introduction (/course/data-structures-introduction/)

Linked Lists (/course/data-structures-linked-lists/)

Doubly Linked Lists (/course/data-structures-doubly-linked-lists/)

Circular Linked Lists (/course/data-structures-circular-linked-lists/)

Stacks (/course/data-structures-stacks/)

Queue (/course/data-structures-queue/)

Trees (/course/data-structures-trees/)

Binary Trees (/course/data-structures-binary-trees/)

Binary Search Trees (/course/data-structures-binary-search-trees/)

Red-Black Trees (/course/data-structures-red-black-trees/)

Red-Black Trees 2 (/course/data-structures-red-black-trees-insertion/)

Red-Black Trees 3 (/course/data-structures-red-black-trees-deletion/)

AVL Trees (/course/data-structures-avl-trees/)

Splay Trees (/course/data-structures-splay-trees/)

Heap (/course/data-structures-heap/)

Priority Queues (/course/data-structures-priority-queues/)

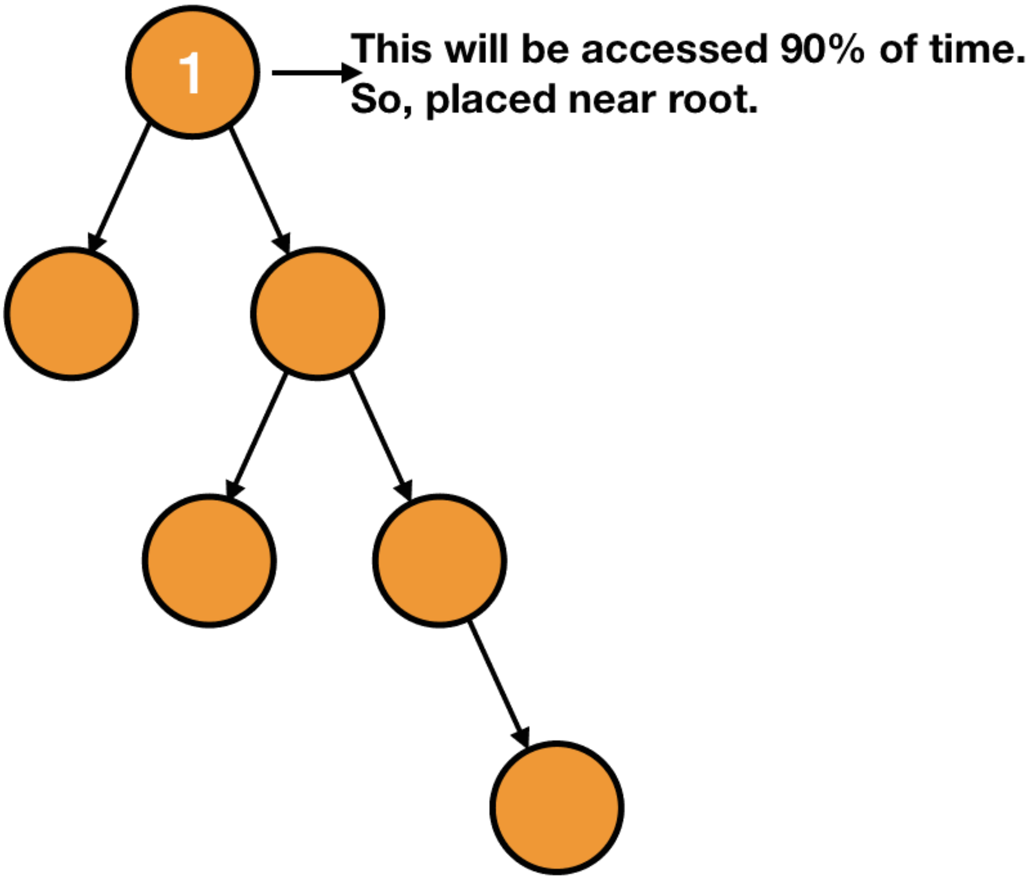
Graph (/course/data-structures-graph/)

Splay Trees

Splay trees are self-adjusting binary search trees i.e., they adjust their nodes after accessing them. So, after searching, inserting or deleting a node, the tree will get adjusted.

(/add_ques

Splay trees put the most recently accessed items near the root based on the principle of locality; 90-10 "rule" which states that 10% of the data is accessed 90% of the time, other 90% of data is only accessed only 10% of the time.



Thus, there is a 90% chance that the elements near the root of a splay tree are going to be accessed in an operation.

Let's learn how these trees adjust nodes on accessing them.

Splaying

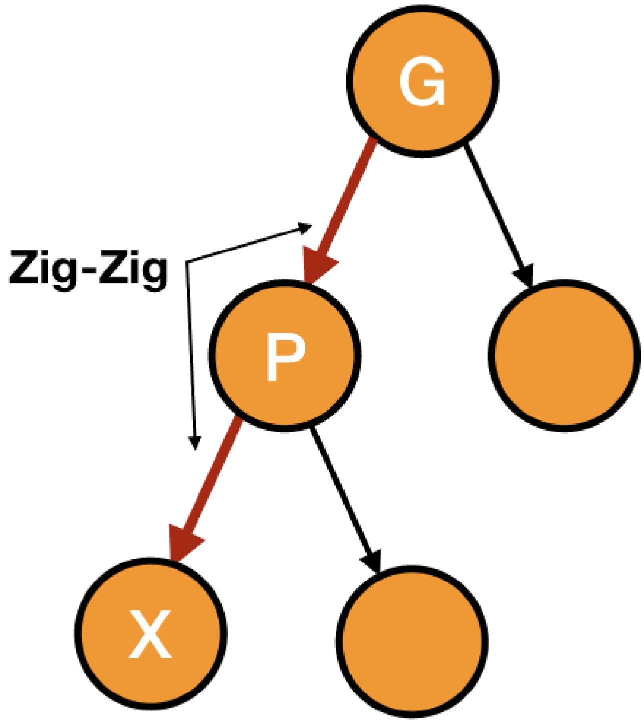
"Splaying" is a process in which a node is transferred to the root by performing suitable rotations. In a splay tree, whenever we access any node, it is splayed to the root. It will be clear with the examples given in this chapter.

There are few terminologies used in this process. Let's learn about those.

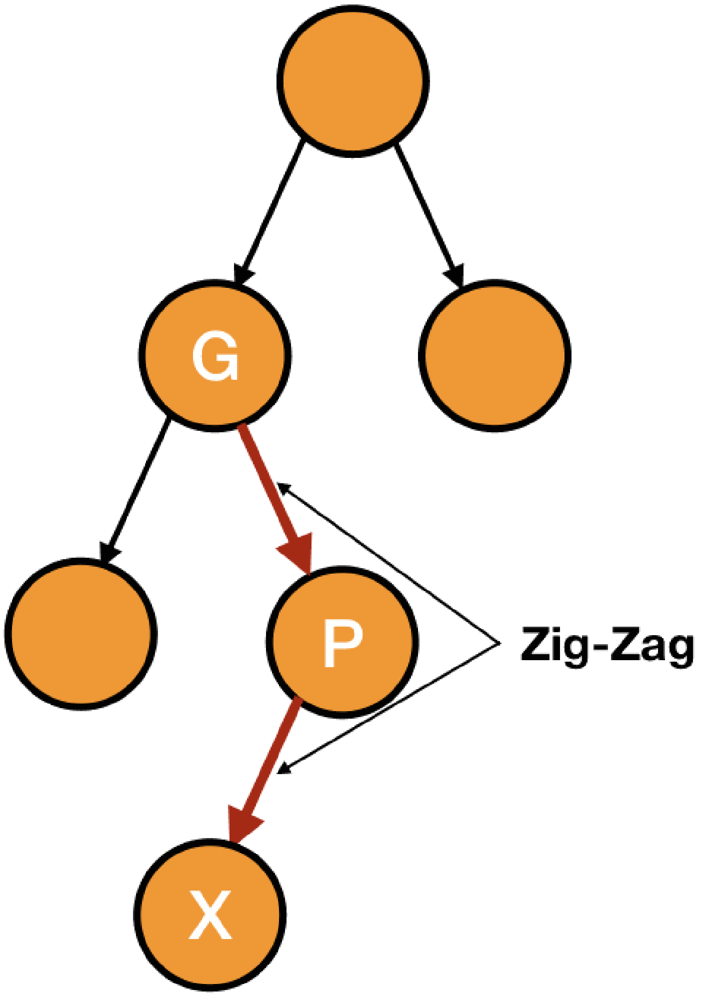
Zig-Zig and Zig-Zag

When the parent and the grandparent of a node are in the same direction, it is **zig-zig**.

?

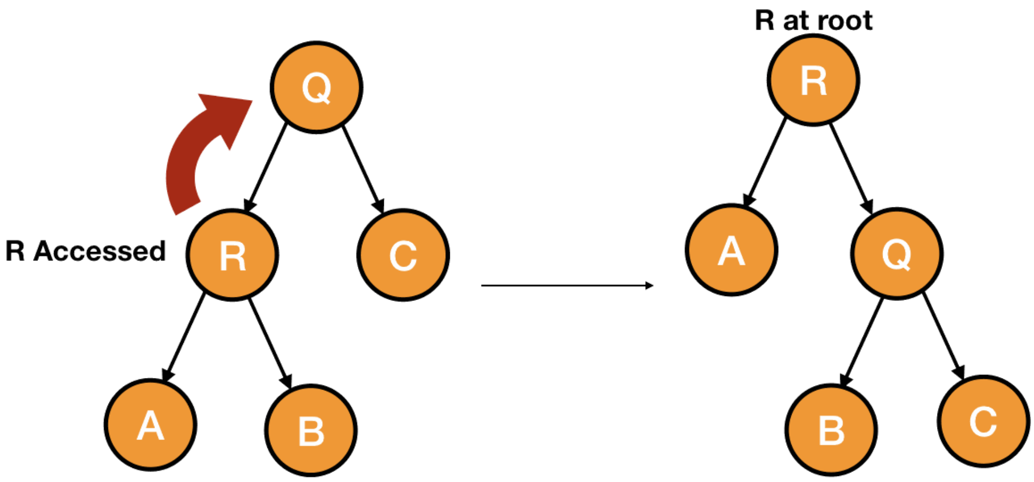


When the parent and the grandparent of a node are in different directions, it is **zig-zag**.

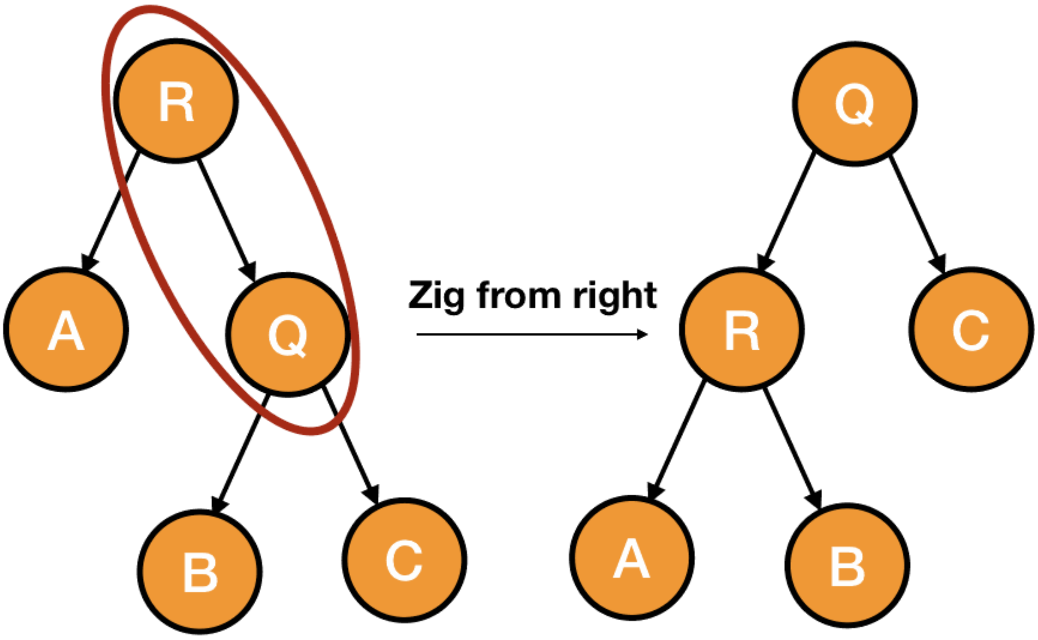


Whenever we access a node, we shift it to the root by using suitable rotations. Let's take the following example.

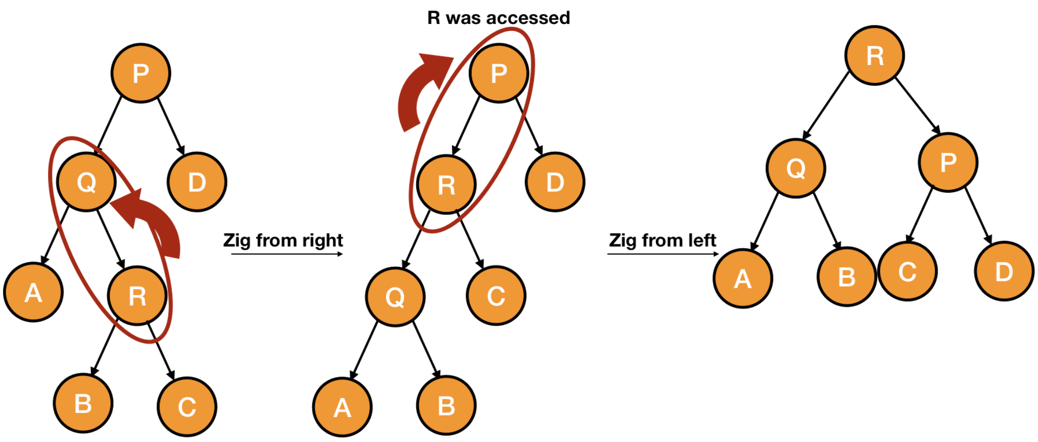
(/add_ques



Here, we have performed a single right rotation and a **single rotation** is termed as "zig".



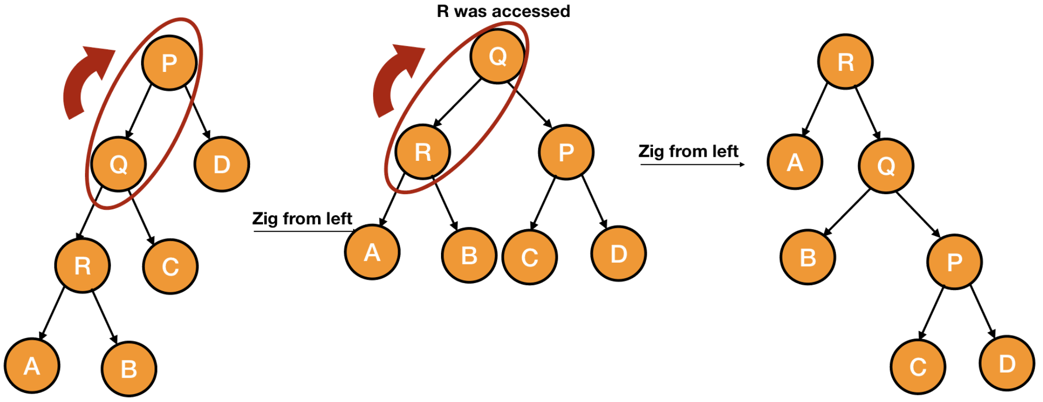
"zig-zag" consists of two rotations of the opposite direction. Take a look at the following example.



ZigZag from left

Let's take a look at the following example in which we have accessed the node *R*.

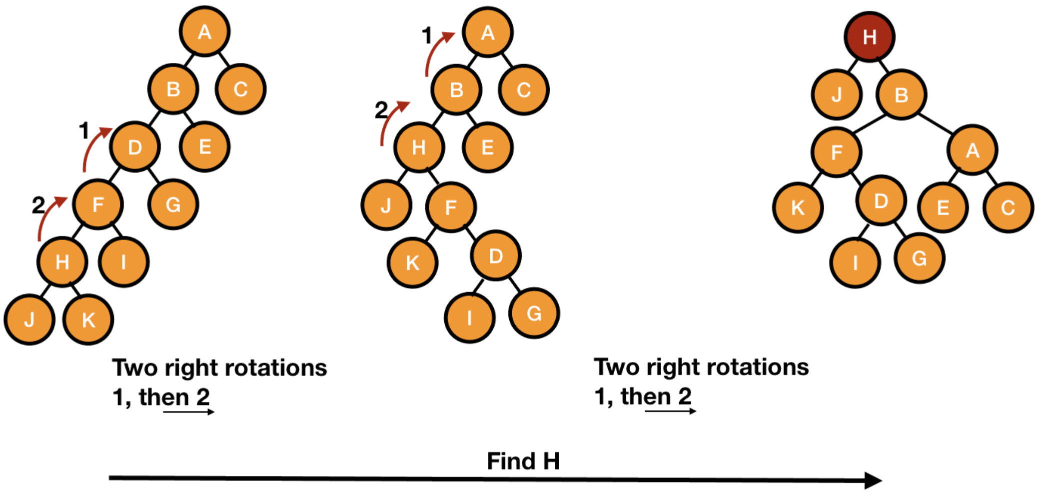
(/add_ques



ZigZig from left

So, we have performed two single rotations of the same direction to bring the node at the root. This is "zig-zig".

Let's take a look at some examples.



A splay tree is not always a balanced tree and may become unbalanced after some operations.

Let's write a code to splay a node to the root.

Code for Splaying

We will start by passing the tree (*T*) and the node which is going to be splayed (*n*).

```
SPLAY(T, n)
```

We have to splay the node *n* to the root. So, we will use a loop and perform suitable rotations and stop it when the node *n* reaches to the root.

```
SPALY(T, n)
  while n.parent != NULL //node is not root
    ...
```

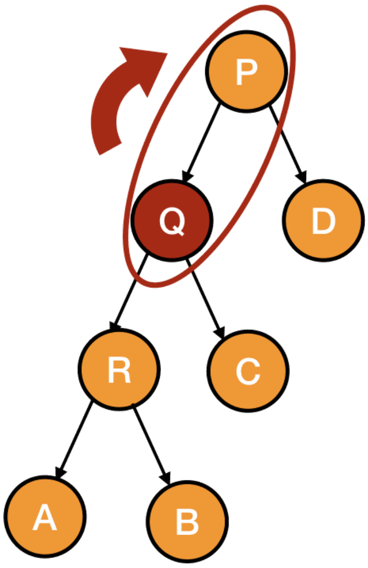
Now, if the node *n* is the direct child of the root, we will just do one rotation, otherwise, we will do two rotations in one iteration.

```
SPALY(T, n)
  while n.parent != NULL //node is not root
    if n.parent == T.root //node is child of root, one rotation
```

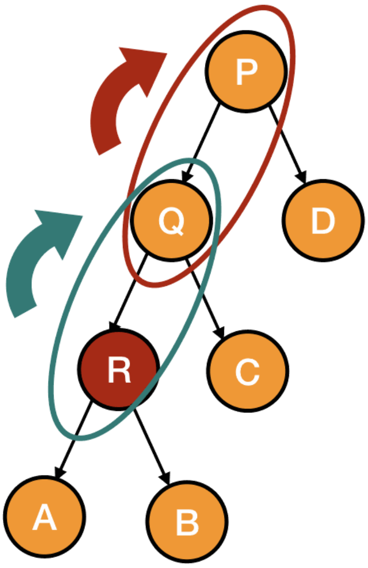
?

(/add_ques

```
      if n == n.parent.left //left child
        RIGHT_ROTATE(T, n.parent)
      else //right child
        LEFT_ROTATE(T, n.parent)
    else //two rotations
      ...
```



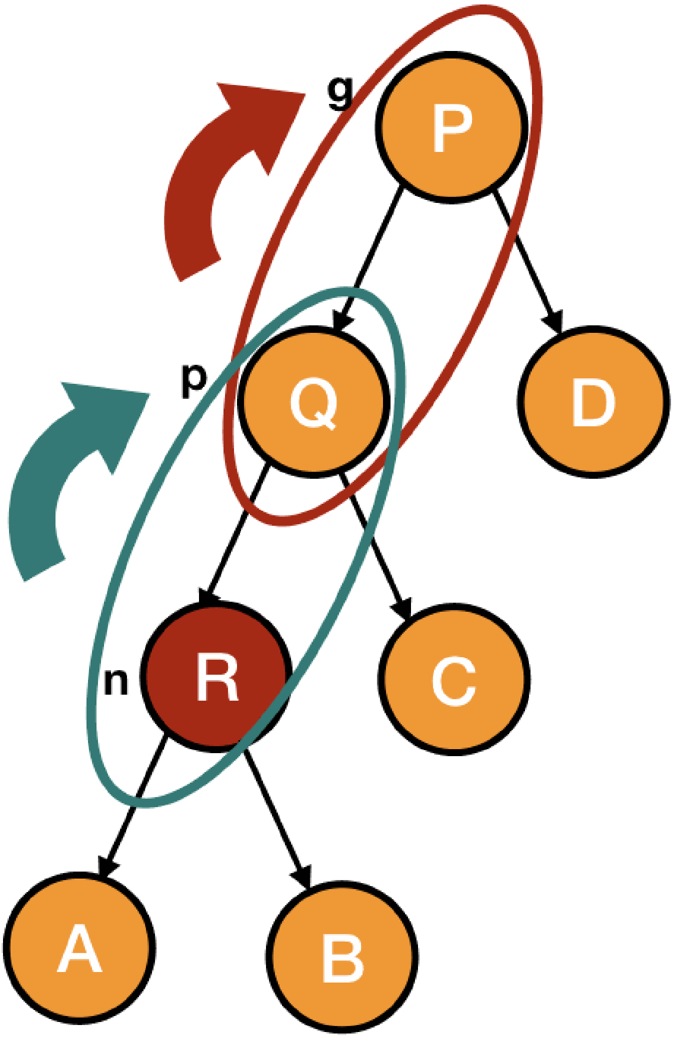
One Rotation, Q is direct child of root



Two Rotations, R is not direct child of root

To perform two rotations, we will first set a variable *p* as the parent of *n* and a variable *g* as grandparent of *n*.

```
SPALY(T, n)
  while n.parent != NULL //node is not root
    if n.parent == T.root //node is child of root, one rotation
      ...
    else //two rotations
      p = n.parent
      g = p.parent
```



Now, we just have to do the rotations.

```
SPALY(T, n)
  while n.parent != NULL //node is not root
    ...
    else //two rotations
      ...
      if n.parent.left == n and p.parent.left == p //both are left children
        RIGHT_ROTATE(T, g)
        RIGHT_ROTATE(T, p)
      else if n.parent.right == n and p.parent.right == p //both are right children
        LEFT_ROTATE(T, g)
        LEFT_ROTATE(T, p)
      else if n.parent.right == n and p.parent.left == p
        LEFT_ROTATE(T, p)
        RIGHT_ROTATE(T, g)
      else
        RIGHT_ROTATE(T, p)
        LEFT_ROTATE(T, g)
```

(/add_ques

```
SPLAY(T, n)
  while n.parent != NULL //node is not root

      if n.parent == T.root //node is child of root, one rotation
          if n == n.parent.left //left child
              RIGHT_ROTATE(T, n.parent)
          else //right child
              LEFT_ROTATE(T, n.parent)

      else //two rotations
          p = n.parent
          g = p.parent

          if n.parent.left == n and p.parent.left == p //both are left children
              RIGHT_ROTATE(T, g)
              RIGHT_ROTATE(T, p)
          else if n.parent.right == n and p.parent.right == p //both are right
              LEFT_ROTATE(T, g)
              LEFT_ROTATE(T, p)
          else if n.parent.right == n and p.parent.left == p
              LEFT_ROTATE(T, p)
              RIGHT_ROTATE(T, g)
          else
              RIGHT_ROTATE(T, p)
              LEFT_ROTATE(T, g)
```

Searching in a Splay Tree

Searching is just the same as a normal binary search tree, we just splay the node which was searched to the root

```
SEARCH(T, n, x)
  if x == n.data
      SPLAY(T, n)
      return n
  else if x < n.data
      return search(T, n.left, x);
  else if x > n.data
      return search(T, n.right, x);
  else
      return NULL
```

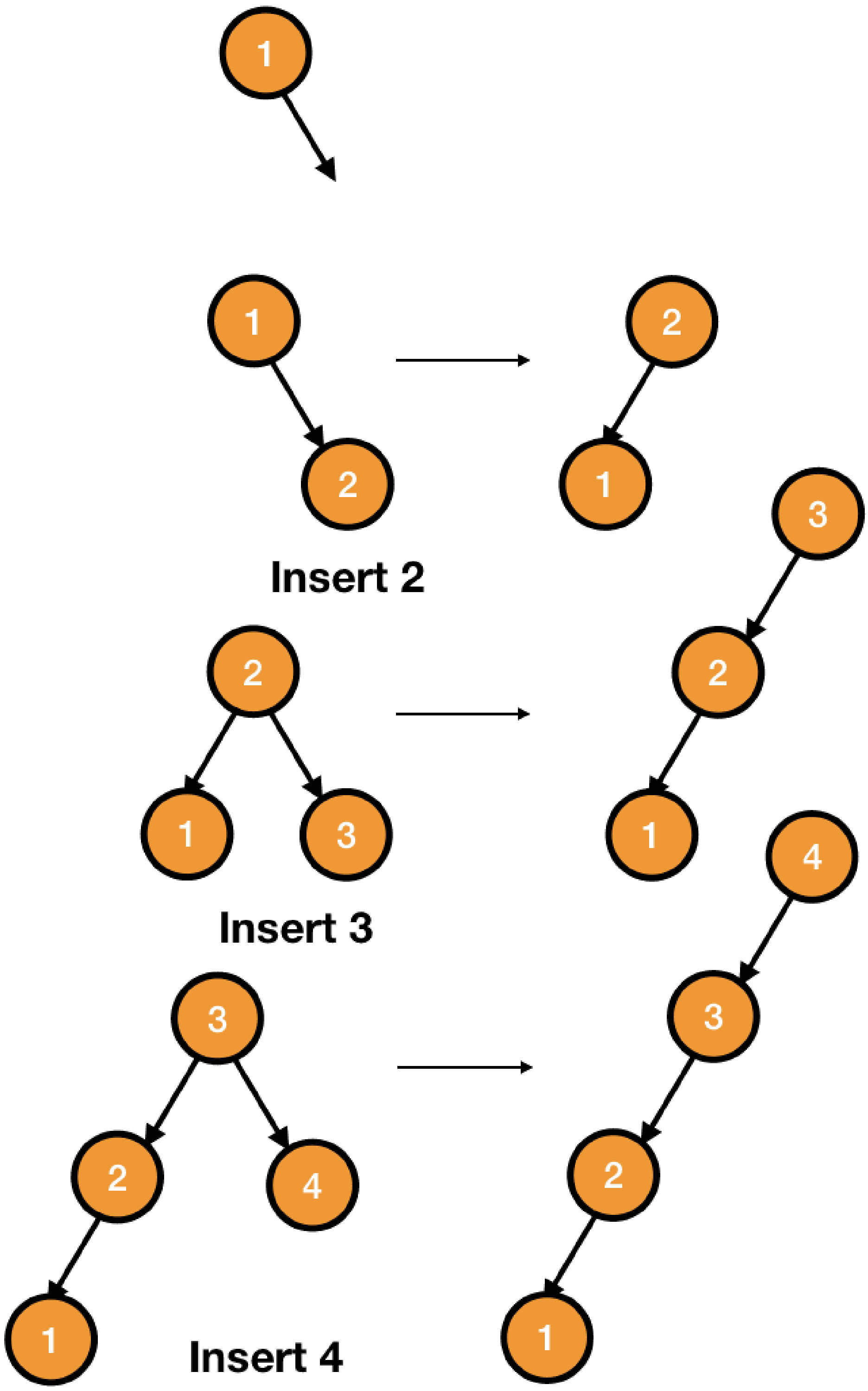
This is the same code that of a binary search tree, we are just splaying the node to root if it is found - `if x == n.data → SPLAY(T, n)`.

Insertion in a Splay Tree

We normally insert a node in a splay tree and splay it to the root.

?

(/add_ques



?

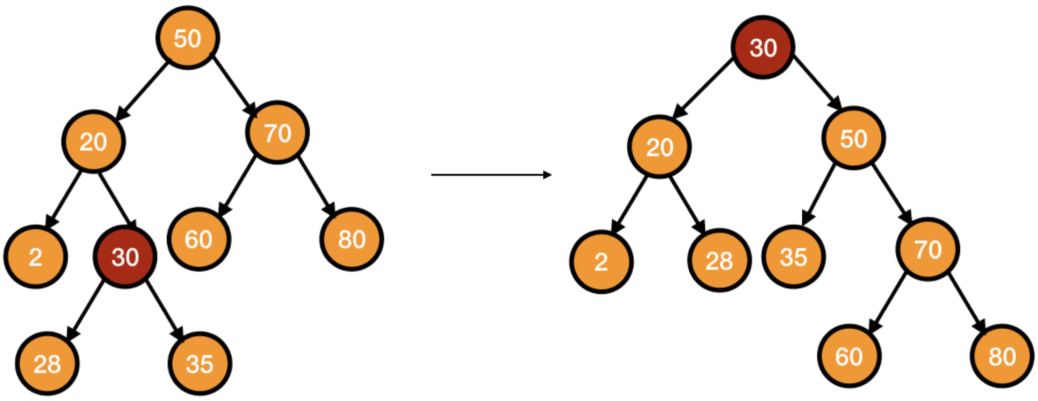
(/add_ques

```
INSERT(T, n)
  temp = T.root
  y = NULL
  while temp != NULL
      y = temp
      if n.data < temp.data
          temp = temp.left
      else
          temp = temp.right
  n.parent = y
  if y==NULL
      T.root = n
  else if n.data < y.data
      y.left = n
  else
      y.right = n

  SPLAY(T, n)
```

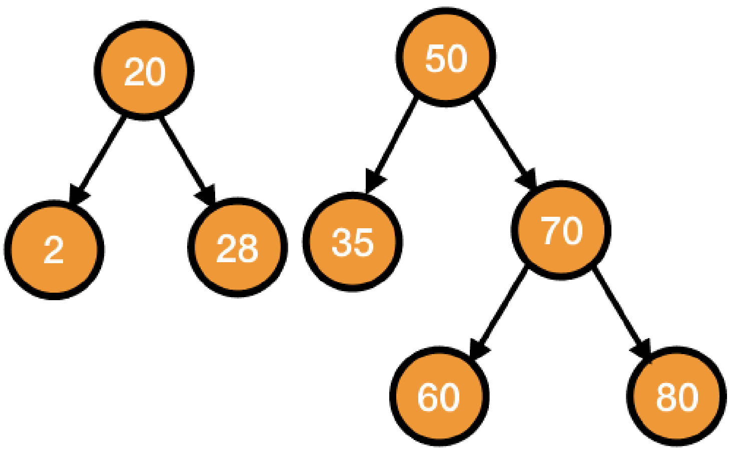
Deletion in a Splay Tree

To delete a node in a splay tree, we first splay that node to the root.



Delete 30

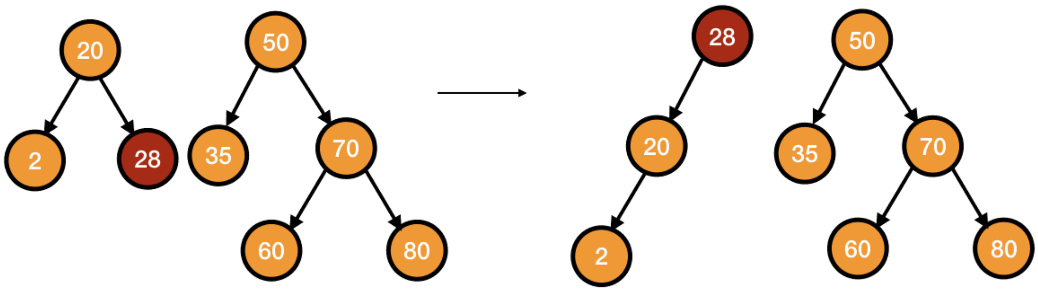
After this, we just delete the root which gives us two subtrees.



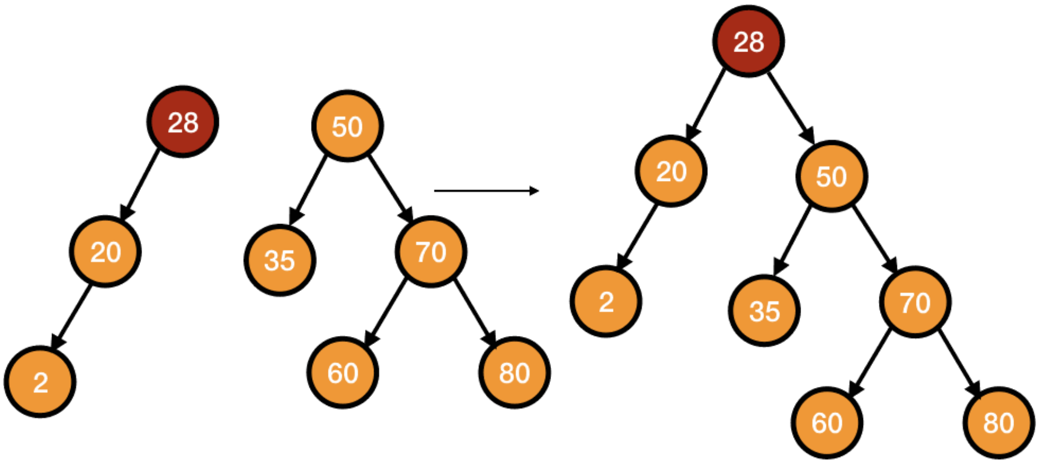
Delete 30

We find the largest element of the left subtree and splay it to the root.

(/add_ques



Lastly, we attach the right subtree as the right child of the left subtree.



Let's write the code for deletion.

Code for Deletion in Spaly Tree

We will first store the left and right subtrees in different variables.

```
DELETE(T, n)
   left_subtree = new splay_tree
   right_subtree = new splay_tree
   left_subtree.root = T.root.left
   right_subtree = T.root.right
   if left_subtree.root != NULL
      left_subtree.root.parent = NULL
   if right_subtree.root != NULL
      right_subtree.root.parent = NULL
```

Then we will find the maximum of the left subtree and splay it to the root.

```
   if left_subtree.root != NULL
      m = MAXIMUM(left_subtree, left_subtree.root)
      SPLAY(left_subtree, m)
```

After that, we will make the right subtree the right child of the new root of the left subtree.

```
   if left_subtree.root != NULL
      ...
      left_subtree.root.right = right_subtree.root
      T.root = left_subtree.root
```

If there is no left subtree, we will make right subtree the new tree.

```
   if left_subtree.root != NULL
      ...
   else
```

(/add_ques

```
T.root = right_subtree.root
```

```
DELETE(T, n)
  left_subtree = new splay_tree
  right_subtree = new splay_tree
  left_subtree.root = T.root.left
  right_subtree = T.root.right
  if left_subtree.root != NULL
      left_subtree.root.parent = NULL
  if right_subtree.root != NULL
      right_subtree.root.parent = NULL

  if left_subtree.root != NULL
      m = MAXIMUM(left_subtree, left_subtree.root)
      SPLAY(left_subtree, m)
      left_subtree.root.right = right_subtree.root
      T.root = left_subtree.root
  else
      T.root = right_subtree.root
```

C **Python** **Java**

?

(/add_ques

```
#include <stdio.h>
#include <stdlib.h>

typedef struct node {
int data;
struct node *left;
struct node *right;
struct node *parent;
}node;

typedef struct splay_tree {
struct node *root;
}splay_tree;

node* new_node(int data) {
node *n = malloc(sizeof(node));
n->data = data;
n->parent = NULL;
n->right = NULL;
n->left = NULL;

return n;
}

splay_tree* new_splay_tree() {
splay_tree *t = malloc(sizeof(splay_tree));
t->root = NULL;

return t;
}

node* maximum(splay_tree *t, node *x) {
while(x->right != NULL)
  x = x->right;
return x;
}

void left_rotate(splay_tree *t, node *x) {
node *y = x->right;
x->right = y->left;
if(y->left != NULL) {
  y->left->parent = x;
}
y->parent = x->parent;
if(x->parent == NULL) { //x is root
  t->root = y;
}
else if(x == x->parent->left) { //x is left child
  x->parent->left = y;
}
else { //x is right child
  x->parent->right = y;
}
y->left = x;
x->parent = y;
}

void right_rotate(splay_tree *t, node *x) {
node *y = x->left;
x->left = y->right;
if(y->right != NULL) {
  y->right->parent = x;
}
y->parent = x->parent;
if(x->parent == NULL) { //x is root
  t->root = y;
}
else if(x == x->parent->right) { //x is left child
  x->parent->right = y;
}
else { //x is right child
  x->parent->left = y;
}
y->right = x;
x->parent = y;
}
```

(/add_ques

```
void splay(splay_tree *t, node *n) {
while(n->parent != NULL) { //node is not root
  if(n->parent == t->root) { //node is child of root, one rotation
    if(n == n->parent->left) {
      right_rotate(t, n->parent);
    }
    else {
      left_rotate(t, n->parent);
    }
  }
  else {
    node *p = n->parent;
    node *g = p->parent; //grandparent

    if(n->parent->left == n && p->parent->left == p) { //both are left children
      right_rotate(t, g);
      right_rotate(t, p);
    }
    else if(n->parent->right == n && p->parent->right == p) { //both are right children
      left_rotate(t, g);
      left_rotate(t, p);
    }
    else if(n->parent->right == n && p->parent->left == p) {
      left_rotate(t, p);
      right_rotate(t, g);
    }
    else if(n->parent->left == n && p->parent->right == p) {
      right_rotate(t, p);
      left_rotate(t, g);
    }
  }
}
}

void insert(splay_tree *t, node *n) {
node *y = NULL;
node *temp = t->root;
while(temp != NULL) {
  y = temp;
  if(n->data < temp->data)
    temp = temp->left;
  else
    temp = temp->right;
}
n->parent = y;

if(y == NULL) //newly added node is root
  t->root = n;
else if(n->data < y->data)
  y->left = n;
else
  y->right = n;

splay(t, n);
}

node* search(splay_tree *t, node *n, int x) {
if(x == n->data) {
  splay(t, n);
  return n;
}
else if(x < n->data)
  return search(t, n->left, x);
else if(x > n->data)
  return search(t, n->right, x);
else
  return NULL;
}

void delete(splay_tree *t, node *n) {
splay(t, n);

splay_tree *left_subtree = new_splay_tree();
left_subtree->root = t->root->left;
if(left_subtree->root != NULL)
  left_subtree->root->parent = NULL;
```

```
splay_tree *right_subtree = new_splay_tree();
right_subtree->root = t->root->right;
if(right_subtree->root != NULL)
  right_subtree->root->parent = NULL;

free(n);

if(left_subtree->root != NULL) {
  node *m = maximum(left_subtree, left_subtree->root);
  splay(left_subtree, m);
  left_subtree->root->right = right_subtree->root;
  t->root = left_subtree->root;
}
else {
  t->root = right_subtree->root;
}
}

void inorder(splay_tree *t, node *n) {
if(n != NULL) {
  inorder(t, n->left);
  printf("%d\n", n->data);
  inorder(t, n->right);
}
}

int main() {
splay_tree *t = new_splay_tree();

node *a, *b, *c, *d, *e, *f, *g, *h, *i, *j, *k, *l, *m;
a = new_node(10);
b = new_node(20);
c = new_node(30);
d = new_node(100);
e = new_node(90);
f = new_node(40);
g = new_node(50);
h = new_node(60);
i = new_node(70);
j = new_node(80);
k = new_node(150);
l = new_node(110);
m = new_node(120);

insert(t, a);
insert(t, b);
insert(t, c);
insert(t, d);
insert(t, e);
insert(t, f);
insert(t, g);
insert(t, h);
insert(t, i);
insert(t, j);
insert(t, k);
insert(t, l);
insert(t, m);

delete(t, a);
delete(t, m);

inorder(t, t->root);

return 0;
}
```

> Heard melodies are sweet, but those unheard, are sweeter
>
> \- John Keats

?

PREV (/course/data-structures-avl-trees/) (/course/data-structures-heap/) NEXT

(/add_ques

New Questions

The Bradford Exchange introduction - **Other**

(/discussion/the-bradford-exchange-introduction)

Why Capital One Stands Out in Banking Excellence - **Other**

(/discussion/why-capital-one-stands-out-in-banking-excellence)

(/add_ques

Access Our AIE02 Exam Dumps - Java

(/discussion/access-our-aie02-exam-dumps)

Increase Your AICP Exam Dumps Readiness - Python

(/discussion/increase-your-aicp-exam-dumps-readiness)

Uncover Our AI-Associate PDF Dumps - Java

(/discussion/uncover-our-ai-associate-pdf-dumps)

Achievement AHPP Exam Dumps with Certs4Exam - Java

(/discussion/achievement-ahpp-exam-dumps-with-certs4exam)

Access Our AHM-540 Dumps PDF - Other

(/discussion/access-our-ahm-540-dumps-pdf)

Ask Yours (/add_question/)

(/discussion/)(https://codesdope-media.nyc3.cdn.digitaloceanspaces.com/prod/media/pdf/ASCII.pd

(/practice/)

(https://www.facebook.com/codesdope)(https://twitter.com/CodesDope)(https://www.linkedin.com/company/codesdope)

Recent Posts

pow() in Python

pow() in Python

(/blog/article/pow-in-python/)

Dutch National Flag problem - Sort 0, 1, 2 in an array

Dutch National Flag problem - Sort 0, 1, 2 in an array

(/blog/article/dutch-national-flag-algorithm/)

memoryview() in Python

memoryview() in Python

(/blog/article/memoryview-in-python/)

next() in Python

next() in Python

(/blog/article/next-in-python/)

Post Yours (/blog/submit-article/) (/add_ques