DAA Project

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TODO

1. Implement and compare the following sorting algorithm : ● Mergesort ● Heapsort ● Quicksort (Using median
2. YET TO COMPLETE - Implement and compare the following search algorithm: ● Linear search ● Binary search Black Tree
3. Implement and compare the following shortest paths algorithm for weighted graph and unweighted graph: ● B Bellman-Ford algorithm ● Dijkstra's algorithm
4. Implement and compare the following Minimum Spanning Trees algorithms: ● Kruskal algorithm ● Prim algor

Note: Graph has been attached as graph.txt

```
# Import required modules
import random
from datetime import datetime
from copy import deepcopy
import time
```

```
# Assign Constants
random_generator_seed = 0
N = 10
```

Sorting Algorithms

```
# Performs a bubble Sort on a given array. This includes inversion Check
# @params array - Array of list to be sorted
# @params inversionCheck - To check for inversions
def bubbleSort(array, inversionCheck = True):
  n = len(array)
  for i in range(n):
    flag = True
    max_index = 0
    for j in range(n - i - 1):
```

```
    for j in range(n - i - 1):
      if(array[j] > array[j+1]):
        temp = array[j]
        array[j] = array[j+1]
        array[j+1] = temp
        flag = False
    if( inversionCheck and flag ):
      break
  return array



# Performs insertion Sort on a given array
# @params array - Array of list to be sorted
def insertionSort(array):
  n = len(array)
  for i in range(1, n):
    key = array[i]
    j = i - 1
    while( j >= 0 and array[j] > key ):
      temp = array[j+1]
      array[j+1] = array[j]
      array[j] = temp
      j -= 1
  return array


def analyzeSortAlgorithm(size, type, o = True):
  array = [ random.randint(0, size) for i in range(size) ]
  if(type == "bubble"):
    sortAlgorithm = bubbleSort
  elif(type == "insertion"):
    sortAlgorithm = insertionSort
  elif(type == "quick"):
    sortAlgorithm = quickSort
  elif(type == "merge"):
    sortAlgorithm = mergeSort
  elif(type == "heap"):
    sortAlgorithm = heapSort
  else:
    print("Sorry, we have no such algorithm mentioned. Try again with a different one'
    return

  print("##################################################")
  print("Analysis for " + type + " sort algorithm for N = " + str(size))

  # Time Average Case
  if(o):
    print("Array: " + str( array ) )
  startTime = datetime.now()
  output = sortAlgorithm( array = array )
  endTime = datetime.now()
  average = endTime - startTime
```

```
    print("Average Case : " + str( average ))
    if(o):
      print("Sorted: " + str( output ) )

    average = average.total_seconds() * 1000
    return average


  def quickSort(array):

    n = len(array)
    array = array

    def quickSortRecursion(low, high):
      if(low >= high):
        return

      mid = ( int )( ( low + high ) / 2 )

      # Finding Median
      if( ( ( array[low] <= array[mid] ) and ( array[mid] <= array[high] ) ) or ( ( arra
        pass
      elif( ( ( array[mid] <= array[low] ) and ( array[low] <= array[high] ) ) or ( ( ar
        temp = array[low]
        array[low] = array[mid]
        array[mid] = temp
      elif( ( ( array[low] <= array[high] ) and ( array[high] <= array[mid] ) ) or ( ( a
        temp = array[high]
        array[high] = array[mid]
        array[mid] = temp

      pivot = array[ mid ]
      array[ mid ] = array[ high ]

      i = low
      j = high - 1
      while( i <= j ):
        while( i < high and array[i] <= pivot ):
          i += 1
        while( j >= low and array[j] >= pivot ):
          j -= 1

        if( i < j ):
          temp = array[ i ]
          array[ i ] = array[ j ]
          array[ j ] = temp
          i += 1
          j -= 1

      array[ high ] = array[ j + 1 ]
      array[ j + 1 ] = pivot
```

```
      quickSortRecursion(low, j)
      quickSortRecursion(j + 2, high)
      return array

    quickSortRecursion(0, n-1)
    return array


  def mergeSort(array):

    def mergeRecursion(array):
      n = len( array )
      if( n == 1 ):
        return array

      # Split into 2 halves
      mid = (int) ( n / 2 )
      leftHalf = array[ 0:mid ]
      rightHalf = array[ mid:n ]

      leftHalf  = mergeRecursion( leftHalf )
      rightHalf = mergeRecursion( rightHalf )

      n_leftHalf = len(leftHalf)
      n_rightHalf = len(rightHalf)
      i = 0
      j = 0

      output = []
      while( ( i < n_leftHalf ) and ( j < n_rightHalf ) ):
        if( leftHalf[i] > rightHalf[j] ):
          output.append( rightHalf[j] )
          j += 1
        else:
          output.append( leftHalf[i] )
          i += 1

      while( i < n_leftHalf ):
        output.append( leftHalf[i] )
        i += 1

      while( j < n_rightHalf ):
        output.append( rightHalf[j] )
        j += 1

      return output

    return mergeRecursion(array)



  def heapSort( array ):
```

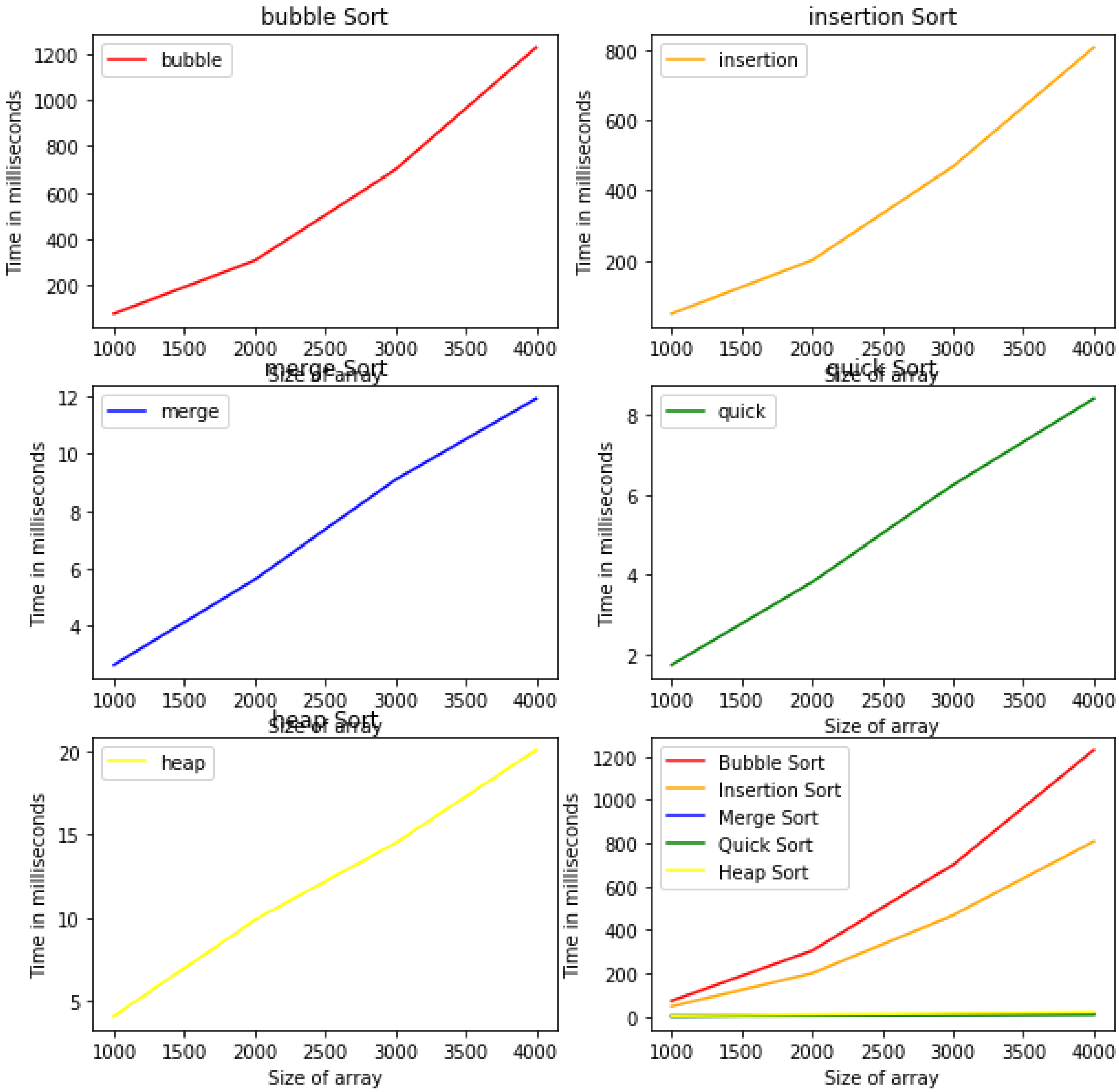
```
    def heapify( array, n, i ):
      largest = i
      left = ( 2*i ) + 1
      right = ( 2*i ) + 2

      if left < n and array[left] > array[i]:
        largest = left

      if right < n and array[right] > array[largest]:
        largest = right

      if i != largest:
        temp = array[i]
        array[i] = array[largest]
        array[largest] = temp

        heapify( array, n, largest )

    n = len( array )

    for i in range(n, -1, -1):
        heapify(array, n, i)

    for i in range(n-1, 0, -1):

        temp = array[i]
        array[i] = array[0]
        array[0] = temp

        heapify(array, i, 0)

    return array


  N = range(1000, 5000, 1000)
  metrics = {
      "N": [],
      "bubble": [],
      "insertion": [],
      "merge": [],
      "quick": [],
      "heap": []
  }

  for n in N:
    metrics['N'].append( n )

    # Performing Bubble Sort
    average = analyzeSortAlgorithm( n, type = "bubble", o = False )
    metrics['bubble'].append( average )

    # Performing Insertion Sort
```

```
    average = analyzeSortAlgorithm( n, type = "insertion", o = False )
    metrics['insertion'].append( average )

    # Performing Merge Sort
    average = analyzeSortAlgorithm( n, type = "merge", o = False )
    metrics['merge'].append( average )

    # Performing Bubble Sort
    average = analyzeSortAlgorithm( n, type = "quick", o = False )
    metrics['quick'].append( average )

    # Performing Bubble Sort
    average = analyzeSortAlgorithm( n, type = "heap", o = False )
    metrics['heap'].append( average )
```

```
Average Case : 0:00:00.072425
###################################################
Analysis for insertion sort algorithm for N = 1000
Average Case : 0:00:00.047102
###################################################
Analysis for merge sort algorithm for N = 1000
Average Case : 0:00:00.002618
###################################################
Analysis for quick sort algorithm for N = 1000
Average Case : 0:00:00.001738
###################################################
Analysis for heap sort algorithm for N = 1000
Average Case : 0:00:00.004026
###################################################
Analysis for bubble sort algorithm for N = 2000
Average Case : 0:00:00.304537
###################################################
Analysis for insertion sort algorithm for N = 2000
Average Case : 0:00:00.199989
###################################################
Analysis for merge sort algorithm for N = 2000
Average Case : 0:00:00.005615
###################################################
Analysis for quick sort algorithm for N = 2000
Average Case : 0:00:00.003817
###################################################
Analysis for heap sort algorithm for N = 2000
Average Case : 0:00:00.009840
###################################################
Analysis for bubble sort algorithm for N = 3000
Average Case : 0:00:00.699027
###################################################
Analysis for insertion sort algorithm for N = 3000
Average Case : 0:00:00.466902
###################################################
Analysis for merge sort algorithm for N = 3000
Average Case : 0:00:00.009094
###################################################
Analysis for quick sort algorithm for N = 3000
Average Case : 0:00:00.006245
###################################################
Analysis for heap sort algorithm for N = 3000
Average Case : 0:00:00.014481
###################################################
Analysis for bubble sort algorithm for N = 4000
Average Case : 0:00:01.230227
###################################################
Analysis for insertion sort algorithm for N = 4000
Average Case : 0:00:00.807138
###################################################
Analysis for merge sort algorithm for N = 4000
Average Case : 0:00:00.011931
###################################################
Analysis for quick sort algorithm for N = 4000
Average Case : 0:00:00.008408
###################################################
Analysis for heap sort algorithm for N = 4000
```

```
    Average Case : 0:00:00.020121
```

```
import matplotlib.pyplot as plt

sortTechniques = ['bubble', 'insertion', 'merge', 'quick', 'heap']
color = ['red', 'orange', 'blue', 'green', 'yellow']

plt.figure(figsize=(10,10))
for i in range(5):
  sortTechnique = sortTechniques[i]

  plt.subplot(3, 2, i + 1)

  plt.plot( metrics['N'], metrics[sortTechnique], color=color[i], label = sortTechniqu
  plt.title(sortTechnique + ' Sort')
  plt.xlabel('Size of array')
  plt.ylabel('Time in milliseconds')

  plt.legend()

plt.subplot(3, 2, 6)
plt.plot( metrics['N'], metrics['bubble'], color=color[0], label = 'Bubble Sort'  )
plt.plot( metrics['N'], metrics['insertion'], color=color[1], label = 'Insertion Sort'
plt.plot( metrics['N'], metrics['merge'], color=color[2], label = 'Merge Sort'  )
plt.plot( metrics['N'], metrics['quick'], color=color[3], label = 'Quick Sort'  )
plt.plot( metrics['N'], metrics['heap'], color=color[4], label = 'Heap Sort'  )

plt.xlabel('Size of array')
plt.ylabel('Time in milliseconds')

plt.legend()
plt.show()
```



Report

It is observed that bubble sort and insertion sort have a time complexity of O(n^2), while other sorts li
time complexity of O(n)

Time Complexity Chart

> Bubble Sort

- Best Case : n
- Average Case : n^2
- Worst Case : n^2

- Space Complexity : 1

> Insertion Sort

- Best Case : n
- Average Case : n^2
- Worst Case : n^2
- Space Complexity : 1

> Merge Sort

- Best Case : n*log(n)
- Average Case : n*log(n)
- Worst Case : n*log(n)
- Space Complexity : n

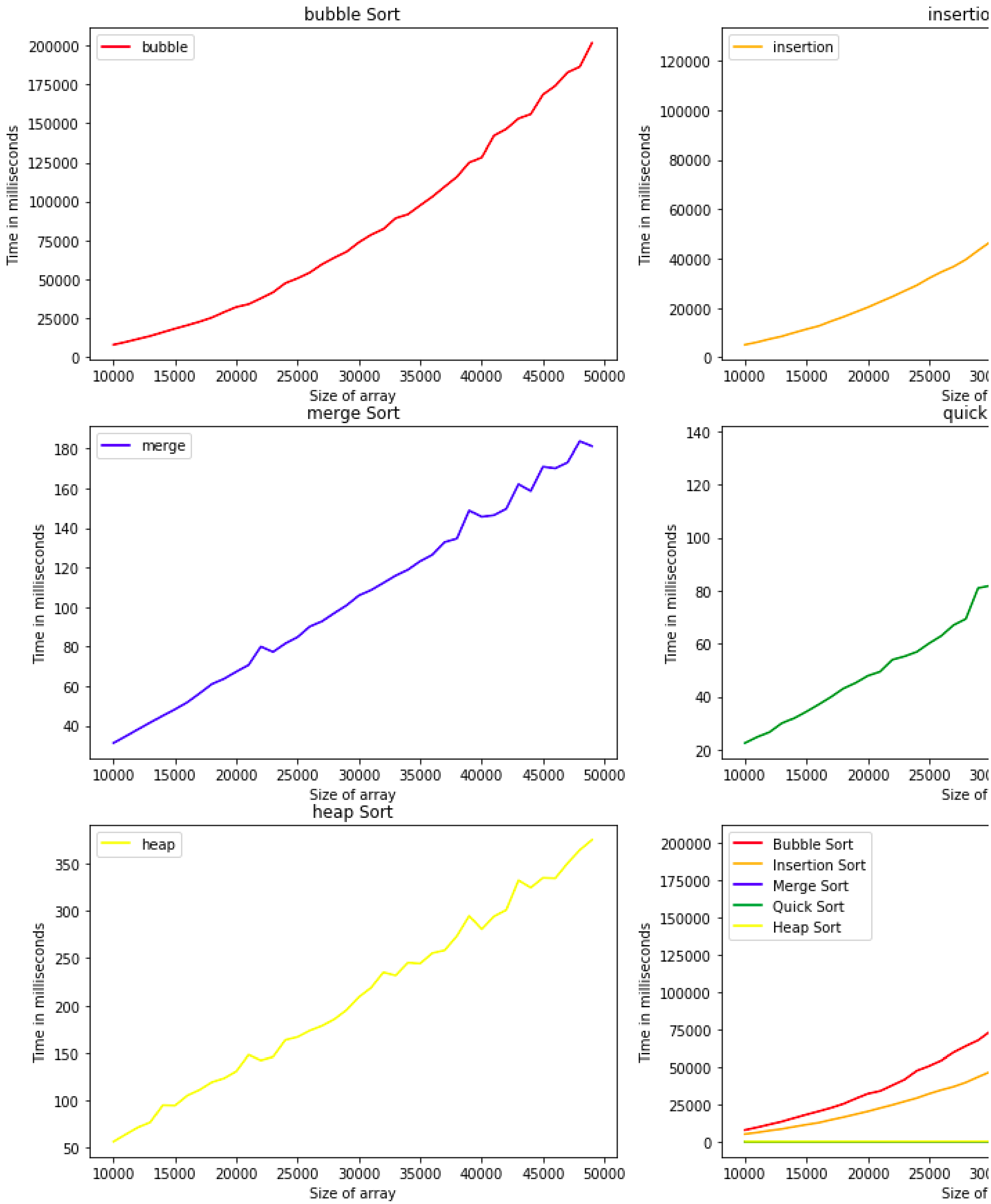
> Quick Sort

- Best Case : n*log(n)
- Average Case : n*log(n)
- Worst Case : n^2
- Space Complexity : n

> Heap Sort

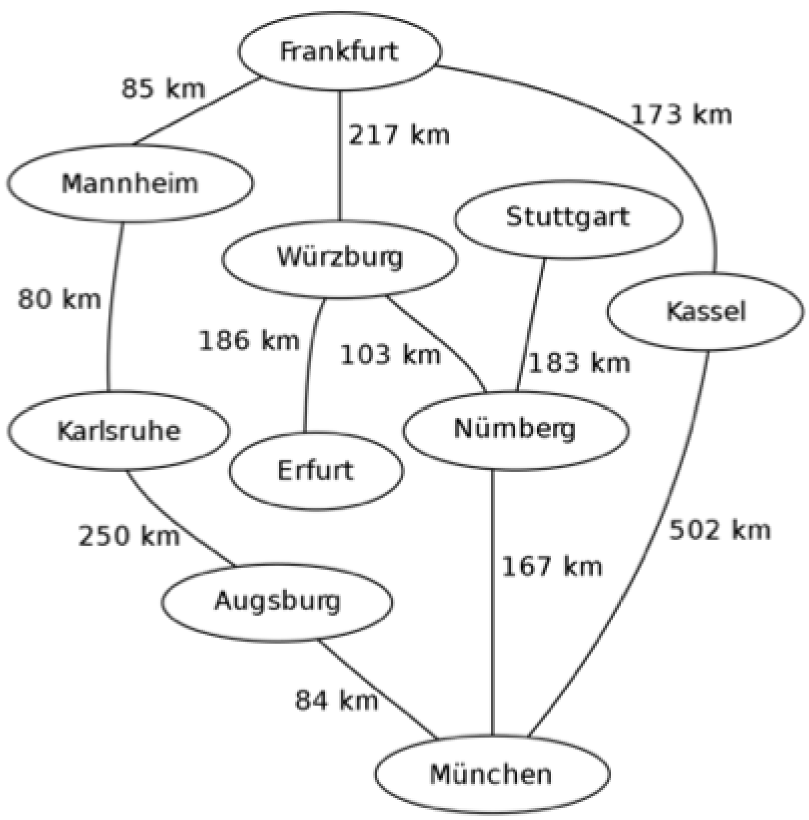
- Best Case : n*log(n)
- Average Case : n*log(n)
- Worst Case : n*log(n)
- Space Complexity : 1

Sample Output from 1000 to 50000 with a step of 1000 Note: Image and output file attached as probl



Shortest Path Algorithms

> Graph




```
from google.colab import drive
drive.mount('/content/drive')
```

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call dri
```

```
import re
from copy import deepcopy
import random
```

```
# Function to read a file
def readFile( fileName ):
  with open( fileName, 'r' ) as f:
    lines = f.read().split( '\n' )
    return lines
```

```
data = readFile( 'graph.txt' )
for line in data:
  print(line)
```

```
s: Frankfurt
p: Frankfurt Mannheim 85
p: Wurzburg Frankfurt 217
p: Frankfurt Kassel 173
p: Mannheim Karlsruhe 80
p: Wurzburg Erfurt 186
p: Numberg Wurzburg 103
p: Numberg Stuttgart 183
p: Kassel Munchen 502
p: Munchen Numberg 167
p: Munchen Augsburg 84
p: Augsburg Karlsruhe 250
```

```
# Create a graph
mainSource = None
path = dict()
directed = False
pathCount = 0

# Add a directed path from source to destination
def addPath( source, destination, distance ):
    if not source in path:
      path[source] = dict()
    if not destination in path[source]:
      path[source][destination] = distance
    else:
      if( path[source][destination] > distance ):
        path[source][destination] = distance
    if not destination in path:
      path[destination] = dict()

# Read file and create a directed graph
for line in data:
  if( re.findall( "^s:", line ) ):
    mainSource = line.split(" ")[1]
  elif( re.findall( "^p:", line ) ):
    pathCount += 1
    words = line.split(" ")
    addPath( source = words[1], destination = words[2], distance = float( words[3] ) )
  elif( re.findall( "^directed" ), line ):
    directed = True

print( "Source: " + mainSource )
print( "Directed: " + str( directed ) )
print( "Path: " + str( path ) )
directedGraph = deepcopy(path)
```

```
Source: Frankfurt
Directed: False
Path: {'Frankfurt': {'Mannheim': 85.0, 'Kassel': 173.0}, 'Mannheim': {'Karlsruhe'
```

```
# Generate a undirected graph
if directed is False:
  for node in directedGraph:
    for myNeighbour in directedGraph[ node ]:
      addPath( source = myNeighbour, destination = node, distance = directedGraph[node

unDirectedGraph = deepcopy(path)
if mainSource is None:
  keys = list( directedGraph.keys() )
  mainSource = keys[ random.randint( 0, len(keys) ) ]

print( "Source: " + mainSource )
print( "Undirected Path: \n" + str(unDirectedGraph) )

# Convert a given graph to unit weights (unweighted)
def convertToUnitDistance( graph ):
  for source in graph:
    for destination in graph[source]:
      graph[source][destination] = 1
  return graph

# Result is the shorted route from a given source
# @params result - dict( location { distance, path } )
def printRoute( result ):
  print("Destination \t Distance \t Path")
  for destination in result:
    print( destination + " \t " + str(result[destination]["distance"]) + " \t " + str(
```

```
Source: Frankfurt
Undirected Path:
{'Frankfurt': {'Mannheim': 85.0, 'Kassel': 173.0, 'Wurzburg': 217.0}, 'Mannheim':
```

```
# Perform BFS on a given directed or undirected graph
def BFS( graph, source ):
  output = dict()
  for key in graph:
    output[key] = dict()
    output[key]["distance"] = float("inf")
    output[key]["path"] = [  ]

  output[source]["distance"] = 0.0

  print( "Source: " + source )
```

```
  visited = [ ]
  queue = [ ]
  queue.append( source )
  visited.append( source )

  while( len(queue) != 0 ):
    start = queue[0]
    del queue[0]
    for myNeighbour in graph[ start ]:
      if not myNeighbour in visited:
        output[myNeighbour]["distance"] = output[start]["distance"] + graph[start][myN
        output[myNeighbour]["path"] = output[start]["path"] + [ start ]
        visited.append( myNeighbour )
        queue.append( myNeighbour )

  return output
```

```
# BFS for undirected weighted Graph
graph = deepcopy(unDirectedGraph)
result = BFS(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         85.0    ['Frankfurt']
Wurzburg         217.0   ['Frankfurt']
Kassel   173.0   ['Frankfurt']
Karlsruhe        165.0   ['Frankfurt', 'Mannheim']
Erfurt   403.0   ['Frankfurt', 'Wurzburg']
Numberg          320.0   ['Frankfurt', 'Wurzburg']
Stuttgart        503.0   ['Frankfurt', 'Wurzburg', 'Numberg']
Munchen          675.0   ['Frankfurt', 'Kassel']
Augsburg         415.0   ['Frankfurt', 'Mannheim', 'Karlsruhe']
```

```
# BFS for directed weighted Graph
graph = deepcopy(directedGraph)
result = BFS(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         85.0    ['Frankfurt']
Wurzburg         945.0   ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Kassel   173.0   ['Frankfurt']
Karlsruhe        165.0   ['Frankfurt', 'Mannheim']
Erfurt   1131.0          ['Frankfurt', 'Kassel', 'Munchen', 'Numberg', 'Wurzburg'
Numberg          842.0   ['Frankfurt', 'Kassel', 'Munchen']
Stuttgart        1025.0          ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Munchen          675.0   ['Frankfurt', 'Kassel']
Augsburg         759.0   ['Frankfurt', 'Kassel', 'Munchen']
```

```
# BFS for undirected unweighted Graph
graph = deepcopy(unDirectedGraph)
graph = convertToUnitDistance(graph)
result = BFS(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         1.0     ['Frankfurt']
Wurzburg         1.0     ['Frankfurt']
Kassel   1.0     ['Frankfurt']
Karlsruhe        2.0     ['Frankfurt', 'Mannheim']
Erfurt   2.0     ['Frankfurt', 'Wurzburg']
Numberg          2.0     ['Frankfurt', 'Wurzburg']
Stuttgart        3.0     ['Frankfurt', 'Wurzburg', 'Numberg']
Munchen          2.0     ['Frankfurt', 'Kassel']
Augsburg         3.0     ['Frankfurt', 'Mannheim', 'Karlsruhe']
```

```
# BFS for directed unweighted Graph
graph = deepcopy(directedGraph)
graph = convertToUnitDistance(graph)
result = BFS(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         1.0     ['Frankfurt']
Wurzburg         4.0     ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Kassel   1.0     ['Frankfurt']
Karlsruhe        2.0     ['Frankfurt', 'Mannheim']
Erfurt   5.0     ['Frankfurt', 'Kassel', 'Munchen', 'Numberg', 'Wurzburg']
Numberg          3.0     ['Frankfurt', 'Kassel', 'Munchen']
Stuttgart        4.0     ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Munchen          2.0     ['Frankfurt', 'Kassel']
Augsburg         3.0     ['Frankfurt', 'Kassel', 'Munchen']
```

```
# Perform BellmanFord on a given directed or undirected graph
```

```
# @params graph - Directed or Undirected Graph
# @params source - Start Node
def BellmanFord( graph, source ):
  output = dict()
  for key in graph:
    output[key] = dict()
    output[key]["distance"] = float("inf")
    output[key]["path"] = [  ]

  output[source]["distance"] = 0.0

  print( "Source: " + source )
  # print( "Graph : " + str(graph) )

  keys = list( output.keys() )

  visited = []
  for i in range( len(keys) ):
    for source in keys:
      for myNeighbour in graph[source]:
        if myNeighbour in graph[source]:
          source_neighbour_distance = output[source]["distance"] + graph[source][myNei
          if output[myNeighbour]["distance"] > source_neighbour_distance:
            output[myNeighbour]["distance"] = source_neighbour_distance
            output[myNeighbour]["path"] = output[source]["path"] + [ source ]

  return output;
```

```
# Bellman Ford for undirected weighted Graph
graph = deepcopy(unDirectedGraph)
result = BellmanFord(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         85.0    ['Frankfurt']
Wurzburg         217.0   ['Frankfurt']
Kassel   173.0   ['Frankfurt']
Karlsruhe        165.0   ['Frankfurt', 'Mannheim']
Erfurt   403.0   ['Frankfurt', 'Wurzburg']
Numberg          320.0   ['Frankfurt', 'Wurzburg']
Stuttgart        503.0   ['Frankfurt', 'Wurzburg', 'Numberg']
Munchen          487.0   ['Frankfurt', 'Wurzburg', 'Numberg']
Augsburg         415.0   ['Frankfurt', 'Mannheim', 'Karlsruhe']
```

```
# Bellman Ford for directed weighted Graph
graph = deepcopy(directedGraph)
result = BellmanFord(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         85.0    ['Frankfurt']
Wurzburg         945.0   ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Kassel   173.0   ['Frankfurt']
Karlsruhe        165.0   ['Frankfurt', 'Mannheim']
Erfurt   1131.0          ['Frankfurt', 'Kassel', 'Munchen', 'Numberg', 'Wurzburg'
Numberg          842.0   ['Frankfurt', 'Kassel', 'Munchen']
Stuttgart        1025.0          ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Munchen          675.0   ['Frankfurt', 'Kassel']
Augsburg         759.0   ['Frankfurt', 'Kassel', 'Munchen']
```

```
# Bellman Ford for undirected unweighted Graph
graph = deepcopy(unDirectedGraph)
graph = convertToUnitDistance(graph)
result = BellmanFord(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         1.0     ['Frankfurt']
Wurzburg         1.0     ['Frankfurt']
Kassel   1.0     ['Frankfurt']
Karlsruhe        2.0     ['Frankfurt', 'Mannheim']
Erfurt   2.0     ['Frankfurt', 'Wurzburg']
Numberg          2.0     ['Frankfurt', 'Wurzburg']
Stuttgart        3.0     ['Frankfurt', 'Wurzburg', 'Numberg']
Munchen          2.0     ['Frankfurt', 'Kassel']
Augsburg         3.0     ['Frankfurt', 'Mannheim', 'Karlsruhe']
```

```
# Bellman Ford for directed unweighted Graph
graph = deepcopy(directedGraph)
graph = convertToUnitDistance(graph)
result = BellmanFord(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         1.0     ['Frankfurt']
Wurzburg         4.0     ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Kassel   1.0     ['Frankfurt']
Karlsruhe        2.0     ['Frankfurt', 'Mannheim']
Erfurt   5.0     ['Frankfurt', 'Kassel', 'Munchen', 'Numberg', 'Wurzburg']
Numberg          3.0     ['Frankfurt', 'Kassel', 'Munchen']
Stuttgart        4.0     ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Munchen          2.0     ['Frankfurt', 'Kassel']
Augsburg         3.0     ['Frankfurt', 'Kassel', 'Munchen']
```

```
# Getting a node with minimum distance on it
```

```
# @params fringe - dict( location { distance, path } )
# @params visited - An array to keep track of visited nodes
def getMinNode( fringe, visited ):
  minDistance = float( "inf" )
  minKey = None
  for key in fringe:
    if not key in visited:
      if fringe[key]["distance"] < minDistance:
        minDistance = fringe[key]["distance"]
        minKey = key
  return minKey

# Perform Dijkstra on a given directed or undirected graph
# @params graph - Directed or Undirected Graph
# @params source - Start Node
def dijkstra( graph, source ):
  output = dict()
  for key in graph:
    output[key] = dict()
    output[key]["distance"] = float("inf")
    output[key]["path"] = [   ]

  output[source]["distance"] = 0.0

  print( "Source: " + source )
  # print( "Graph : " + str(graph) )

  keys = list( output.keys() )

  visited = []
  for i in range( len(keys) ):
    start = getMinNode( output, visited )
    visited.append( start )
    for myNeighbour in graph[start]:
      if ( not myNeighbour in visited ) and ( myNeighbour in graph[start] ) :
        z = graph[start][myNeighbour] + output[ start ]["distance"];
        if output[myNeighbour]["distance"] > z:
          output[myNeighbour] = {
              "distance": z,
              "path": output[ start ]["path"] + [start]
          }
  return output;



# Dijkstra for undirected weighted Graph
graph = deepcopy(unDirectedGraph)
result = dijkstra(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         85.0    ['Frankfurt']
Wurzburg         217.0   ['Frankfurt']
Kassel   173.0   ['Frankfurt']
Karlsruhe        165.0   ['Frankfurt', 'Mannheim']
Erfurt   403.0   ['Frankfurt', 'Wurzburg']
Numberg          320.0   ['Frankfurt', 'Wurzburg']
Stuttgart        503.0   ['Frankfurt', 'Wurzburg', 'Numberg']
Munchen          487.0   ['Frankfurt', 'Wurzburg', 'Numberg']
Augsburg         415.0   ['Frankfurt', 'Mannheim', 'Karlsruhe']
```

```
# Dijkstra for directed weighted Graph
graph = deepcopy(directedGraph)
result = dijkstra(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         85.0    ['Frankfurt']
Wurzburg         945.0   ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Kassel   173.0   ['Frankfurt']
Karlsruhe        165.0   ['Frankfurt', 'Mannheim']
Erfurt   1131.0          ['Frankfurt', 'Kassel', 'Munchen', 'Numberg', 'Wurzburg'
Numberg          842.0   ['Frankfurt', 'Kassel', 'Munchen']
Stuttgart        1025.0          ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Munchen          675.0   ['Frankfurt', 'Kassel']
Augsburg         759.0   ['Frankfurt', 'Kassel', 'Munchen']
```

```
# Dijkstra for for undirected unweighted Graph
graph = deepcopy(unDirectedGraph)
graph = convertToUnitDistance(graph)
result = dijkstra(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         1.0     ['Frankfurt']
Wurzburg         1.0     ['Frankfurt']
Kassel   1.0     ['Frankfurt']
Karlsruhe        2.0     ['Frankfurt', 'Mannheim']
Erfurt   2.0     ['Frankfurt', 'Wurzburg']
Numberg          2.0     ['Frankfurt', 'Wurzburg']
Stuttgart        3.0     ['Frankfurt', 'Wurzburg', 'Numberg']
Munchen          2.0     ['Frankfurt', 'Kassel']
Augsburg         3.0     ['Frankfurt', 'Mannheim', 'Karlsruhe']
```

```
# Dijkstra for for directed unweighted Graph
graph = deepcopy(directedGraph)
```

```
graph = convertToUnitDistance(graph)
result = dijkstra(graph, mainSource)
printRoute(result)
```

```
Source: Frankfurt
Destination      Distance        Path
Frankfurt        0.0     []
Mannheim         1.0     ['Frankfurt']
Wurzburg         4.0     ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Kassel   1.0     ['Frankfurt']
Karlsruhe        2.0     ['Frankfurt', 'Mannheim']
Erfurt   5.0     ['Frankfurt', 'Kassel', 'Munchen', 'Numberg', 'Wurzburg']
Numberg          3.0     ['Frankfurt', 'Kassel', 'Munchen']
Stuttgart        4.0     ['Frankfurt', 'Kassel', 'Munchen', 'Numberg']
Munchen          2.0     ['Frankfurt', 'Kassel']
Augsburg         3.0     ['Frankfurt', 'Kassel', 'Munchen']
```

Report

We can see that Bellman Ford and Dijkstra given the same output. While, the BFS gives just another rc undirected weighted graph generates a longer route in BFS when compared to other algorithms

Note: The above program has been developed as Adjaceny List

Thus showing Dijkstra algorithm is comparitively better

Time Complexity Chart

> BFS

- Time Complexity - Adjaceny Matrix : V^2
- Time Complexity - Adjaceny List : V + E

> Bellman Ford Algorithm

- Time Complexity - Adjaceny Matrix : V^2
- Time Complexity - Adjaceny List : V * E

> Dijkstra Algorithm

- Time Complexity - Adjaceny Matrix : V^2
- Time Complexity - Adjaceny List : E * log(V)

Minimum Spanning Tree Algorithms

```
from google.colab import drive
drive.mount('/content/drive')
```

```
drive.mount('/content/drive')
```

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call dri
```

```
import re
from copy import deepcopy
import random


# Function to read a file
def readFile( fileName ):
  with open( fileName, 'r' ) as f:
    lines = f.read().split( '\n' )
    return lines

data = readFile( 'graph.txt' )
for line in data:
  print(line)
```

```
s: Frankfurt
p: Frankfurt Mannheim 85
p: Wurzburg Frankfurt 217
p: Frankfurt Kassel 173
p: Mannheim Karlsruhe 80
p: Wurzburg Erfurt 186
p: Numberg Wurzburg 103
p: Numberg Stuttgart 183
p: Kassel Munchen 502
p: Munchen Numberg 167
p: Munchen Augsburg 84
p: Augsburg Karlsruhe 250
```

```
# Create a graph

mainSource = None
path = dict()
directed = False
pathCount = 0

# Add a directed path from source to destination
def addPath( source, destination, distance ):
    if not source in path:
      path[source] = dict()
    if not destination in path[source]:
      path[source][destination] = distance
    else:
      if( path[source][destination] > distance ):
        path[source][destination] = distance
    if not destination in path:
      path[destination] = dict()
```

```
# Read file and create a directed graph
for line in data:
  if( re.findall( "^s:", line ) ):
    mainSource = line.split(" ")[1]
  elif( re.findall( "^p:", line ) ):
    pathCount += 1
    words = line.split(" ")
    addPath( source = words[1], destination = words[2], distance = float( words[3] ) )
  elif( re.findall( "^directed" ), line ):
    directed = True

print( "Source: " + mainSource )
print( "Directed: " + str( directed ) )
print( "Path: " + str( path ) )
directedGraph = deepcopy(path)
```

```
Source: Frankfurt
Directed: False
Path: {'Frankfurt': {'Mannheim': 85.0, 'Kassel': 173.0}, 'Mannheim': {'Karlsruhe'
```

```
if directed is False:
  for node in directedGraph:
    for myNeighbour in directedGraph[ node ]:
      addPath( source = myNeighbour, destination = node, distance = directedGraph[node

unDirectedGraph = deepcopy(path)
if mainSource is None:
  keys = list( directedGraph.keys() )
  mainSource = keys[ random.randint( 0, len(keys) ) ]

print( "Source: " + mainSource )
print( "Undirected Path: \n" + str(unDirectedGraph) )

def printMST( mst ):
  print( "Minimum Spanning Tree: " )
  for node in mst:
    if not mst[node]["parent"] is None:
      print(mst[node]["parent"] + " -- " + node + " : " + str( mst[node]["distance"] )
```

```
Source: Frankfurt
Undirected Path:
{'Frankfurt': {'Mannheim': 85.0, 'Kassel': 173.0, 'Wurzburg': 217.0}, 'Mannheim':
```

```
# Prims algorithm on a undirected Graph
# To check if a given graph is Minimum Spanning Tree or not

def getMinNode( mst, visited ):
  minDistance = float( "inf" )
  minKey = None
  for key in mst:
```

```
  for key in mst:
    if not key in visited:
      if mst[key]["distance"] < minDistance:
        minDistance = mst[key]["distance"]
        minKey = key
  return minKey

def prim( graph, source ):
  mst = dict()
  for key in graph:
    mst[key] = dict()
    mst[key]["distance"] = float("inf")
    mst[key]["parent"] = None

  mst[source]["distance"] = 0.0
  print( "Source: " + source )
  print( "Graph : " + str(graph) )

  keys = list( mst.keys() )

  visited = []
  for i in range( len(keys) ):
    start = getMinNode( mst, visited )
    visited.append( start )
    for myNeighbour in graph[start]:
      if ( not myNeighbour in visited ) and ( myNeighbour in graph[start] ) :
        if mst[myNeighbour]["distance"] > graph[start][myNeighbour]:
          mst[myNeighbour] = {
              "distance": graph[start][myNeighbour],
              "parent": start
          }

  return mst

print("PRIMS OUTPUT")
graph = deepcopy(unDirectedGraph)
mst = prim(graph, mainSource)
printMST(mst)
```

```
PRIMS OUTPUT
Source: Frankfurt
Graph : {'Frankfurt': {'Mannheim': 85.0, 'Kassel': 173.0, 'Wurzburg': 217.0}, 'Ma
Minimum Spanning Tree:
Frankfurt -- Mannheim : 85.0
Frankfurt -- Wurzburg : 217.0
Frankfurt -- Kassel : 173.0
Mannheim -- Karlsruhe : 80.0
Wurzburg -- Erfurt : 186.0
Wurzburg -- Numberg : 103.0
Numberg -- Stuttgart : 183.0
Numberg -- Munchen : 167.0
Munchen -- Augsburg : 84.0
```

```
# Kruskal Algorithm

def getMinEdge( graph ):
  minWeight = float("inf")
  minSource = None
  minDestination = None
  for source in graph:
    for destination in graph[source]:
      if minWeight > graph[source][destination]:
        minWeight = graph[source][destination]
        minSource = source
        minDestination = destination

  return minSource, minDestination, minWeight

def getMySet( sets, node ):

  for i in range( len(sets) ):
    if node in sets[i]:
      return i
  return -1

def joinSets( sets, index_A, index_B ):
  A = sets[index_A]
  B = sets[index_B]
  jointSet = A + B
  sets.append(jointSet)
  sets.remove(A)
  sets.remove(B)

def kruskal( graph ):
  sets = [ ]
  mst = dict( )
  for i in range(pathCount):
    source, destination, distance = getMinEdge( graph )
    graph[source][destination] = float( "inf" )
    graph[destination][source] = float( "inf" )
    sourceSet = getMySet( sets, source )
    destinationSet = getMySet( sets, destination )
    if sourceSet == destinationSet and sourceSet != -1:
      continue

    if sourceSet == -1 and destinationSet == -1:
      sets.append( [ source, destination ] )
    elif sourceSet == -1:
      sets[ destinationSet ].append( source )
    elif destinationSet == -1:
      sets[ sourceSet ].append( destination )
    else:
      joinSets( sets, sourceSet, destinationSet )
    mst[destination] = {
```

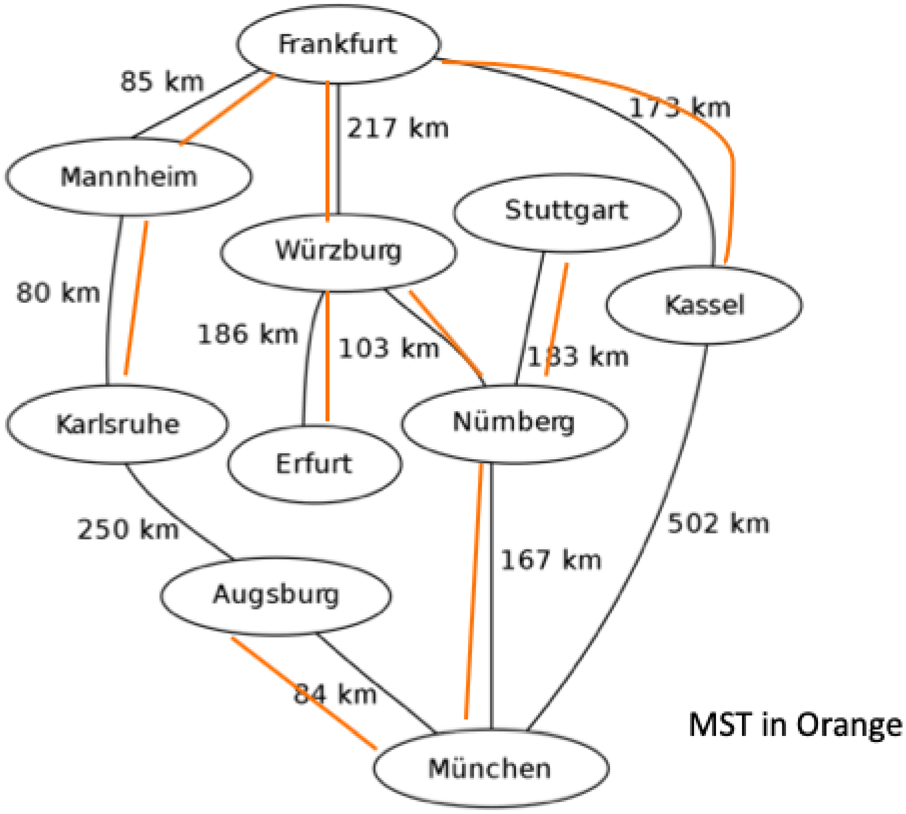
```
        "distance": distance,
        "parent": source
      }
  return mst

print("KRUSKAL OUTPUT")
graph = deepcopy(unDirectedGraph)
mst = kruskal(graph)
printMST(mst)
```

```
KRUSKAL OUTPUT
Minimum Spanning Tree:
Mannheim -- Karlsruhe : 80.0
Munchen -- Augsburg : 84.0
Frankfurt -- Mannheim : 85.0
Wurzburg -- Numberg : 103.0
Numberg -- Munchen : 167.0
Frankfurt -- Kassel : 173.0
Numberg -- Stuttgart : 183.0
Wurzburg -- Erfurt : 186.0
Frankfurt -- Wurzburg : 217.0
```

Report

This is the MST generated for both the algorithms (Prim and Kruskal)

> Generated MST:



Note: The following has been done with adjacent matrix

Time Complexity Chart

> Prims

- Time Complexity - Adjaceny Matrix : V^2
- Time Complexity - Adjaceny List : V + E
- Time Complexity - Binary Heap : V * E * log(V)
- Time Complexity - Fibonacci Heap : V + (E * log(V))

> Kruskal

- Time Complexity - Adjaceny Matrix : V^2
- Time Complexity - Adjaceny List : E * log(V)