PROJECT REPORT: NETWORK TOPOLOGY CHARACTERISTICS

- **Introduction:**
  In this Project we have implemented Network Topology Characteristics in Java. Each complex network (or class of networks) presents specific topological features which characterize its connectivity and highly influence the dynamics of processes executed on the network. The analysis, discrimination, and synthesis of complex networks therefore rely on the use of measurements capable of expressing the most relevant topological features.

Formal Definition of Topology Parameters implemented:

Degree of a node and its distribution:

1. Any graph or network has two basic components - nodes and edges. An un-weighted network can be represented as an adjacency matrix (A). Any element of adjacency matrix $a_{ij.}$
2. Degree distribution is the probability distribution of these degrees over the network. N the total number of nodes in the network. Higher average degree implies good inter-connectivity among the nodes in the network.
3. Degree of node is the number of connections it has with the other nodes.

$$k_i = \sum_j a_{ij}.$$

$$P(k) = \frac{N(k)}{\sum N(k)}.$$

Strength of a node and its distribution

1. If wij is the number of possible interactions between any ith and jth nodes, then the strength (si) of a node i is given by:

$$s_i = \sum_j a_{ij} w_{ij}.$$

2. The spread in the strength of a node has been characterized by a distribution function P(s); where

$$P(s) = \frac{N(s)}{\sum N(s)}$$

Average Weight of a node

1. If wij is the number of possible interactions between any ith and jth atoms, then the average weight < wij > of an atom i is given by

$$< w_{ij} >= \frac{\sum_i \sum_j w_{ij}}{M}.$$

Where M is the total number of interactions among atoms.

Characteristic path length of a network

1. The characteristic path length (L) of a network is the shortest path length between two nodes averaged over all pairs of nodes and is given by:

$$L = \frac{\sum_i \sum_j L_{i,j}}{N(N-1)}$$

2. where Li,j is the shortest path length between ith node and jth node.
Higher characteristic path length implies network is almost in liner chain and lower characteristic path length shows the network is in compact form.

Pseudo code:

1. Degree of a node and its distribution:

Store the Graph nodes in getGraphnodes functions and create a 2X2 Adjacency Matrix to store the directed Graph.
Define a function getDegreeOfGraph(String[] graphNodes, **int**[][] adjacencyMatrix)

Create a HashMap to store graph node and corresponding degree

```
for (int i = 0; i < graphNodes.length; i++) {
    String graphNode = graphNodes[i];
    int[] edges = adjacencyMatrix[i];
    int degree = 0;

    for (int edge : edges) {
        if (edge > 0) {
```

```
                degree++;
            }
        }

        graphDegree.put(graphNode, degree);
    }

    return graphDegree;
}
```

2. Strength of a node and its distribution

Define a function getStrengthOfNode
Create a HashMap graphStength
Parse through graphnodes to store them in string

```
    for (int i = 0; i < graphNodes.length; i++) {
        String graphNode = graphNodes[i];
        int[] edges = adjacencyMatrix[i];
//Initialize strength
        int strength = 0;
//whenever edge is greater than zero increment the strength of node
        for (int edge : edges) {
            if (edge > 0) {
                strength += edge;
            }
        }
//storing in hashmap
        graphStrength.put(graphNode, strength);
    }

    return graphStrength;
}
```

3. Average Weight of a node

Define a method getAverageWeight for calculating Average Weight of a node
Use Hash map for storing the weights

```
    for (int i = 0; i < graphNodes.length; i++) {
        String graphNode = graphNodes[i];
        int[] edges = adjacencyMatrix[i];
//Initialize degree to 0
        int degree = 0;
```

```
//Initialize strength
        int strength = 0;
//whenever edge is greater than zero increment the strength of node
        for (int edge : edges) {
            if (edge > 0) {
                strength += edge;
                degree++;
            }
        }
// Calculate the average strength by dividing the strength by degree
        int avgStrength = 0;
        if (degree > 0) {
            avgStrength = strength / degree;
        }

        averageWeight.put(graphNode, avgStrength);
    }
// Return Average Weight
    return averageWeight;
}
```

4. Characteristic path length of a network

Define allShortestPathLenth method, location 1-d array, distance 2-d array

```
// obtain a large number greater than all edge weights
      large = 1;
      for (k=1; k<=m; k++)
        large += weight[k];

      // set up the distance matrix
      for (i=1; i<=n; i++)
        for (j=1; j<=n; j++)
          distance[i][j] = (i == j) ? 0 : large;
      for (k=1; k<=m; k++) {
        i = nodei[k];
        j = nodej[k];
        if (directed[k])
          distance[i][j] = weight[k];
        else
          distance[i][j] = distance[j][i] = weight[k];
      }

      if (root != 1) {
```

```
  // interchange rows 1 and root
  for (i=1; i<=n; i++) {
    temp = distance[1][i];
    distance[1][i] = distance[root][i];
    distance[root][i] = temp;
  }
  // interchange columns 1 and root
  for (i=1; i<=n; i++) {
    temp = distance[i][1];
    distance[i][1] = distance[i][root];
    distance[i][root] = temp;
  }
}
nodeu = 1;
n2 = n + 2;
for (i=1; i<=n; i++) {
  location[i] = i;
  mindistance[i] = distance[nodeu][i];
}
for (i=2; i<=n; i++) {
  k = n2 - i;
  minlen = large;
  for (j=2; j<=k; j++) {
    nodev = location[j];
    temp = mindistance[nodeu] + distance[nodeu][nodev];
    if (temp < mindistance[nodev]) mindistance[nodev] = temp;
    if (minlen > mindistance[nodev]) {
      minlen = mindistance[nodev];
      minv = nodev;
      minj = j;
    }
  }
  nodeu = minv;
  location[minj] = location[k];
}
if (root != 1) {
  mindistance[1] = mindistance[root];
  mindistance[root] = 0;
  // interchange rows 1 and root
  for (i=1; i<=n; i++) {
    temp = distance[1][i];
    distance[1][i] = distance[root][i];
    distance[root][i] = temp;
  }
  // interchange columns 1 and root
  for (i=1; i<=n; i++) {
```

```
        temp = distance[i][1];
        distance[i][1] = distance[i][root];
        distance[i][root] = temp;
      }
    }
  }
```

Time Complexity

In terms of runtime, our implementation for each method is as follow:

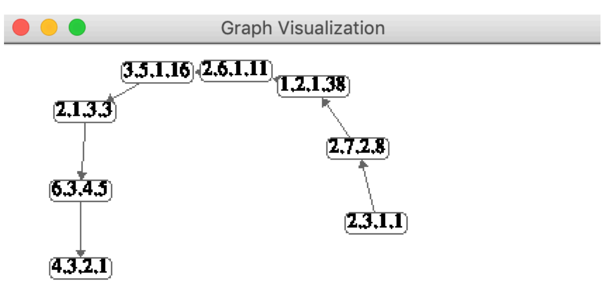
where N is the number of nodes in the network.

1. Degree of node: O(N)
2. Strength of node: O(N)
3. Average Weight of node: O(N)
4. Characteristic path length of node: O(N^3)

Overall Time Complexity is : O(N^3)

Network analysis of a given graph example and Results

Given Graph:



Results: Degree of node:

```
/Library/Java/JavaVirtualMachines/adoptopenjdk-8.jdk/Contents/Home/bin/java ...
Graph Node -> Degree
2.1.3.3 -> 1
1.2.1.38 -> 1
4.3.2.1 -> 0
2.3.1.1 -> 1
2.7.2.8 -> 1
6.3.4.5 -> 1
3.5.1.16 -> 1
2.6.1.11 -> 1
```

Strength of node:

```
Graph Node -> Strength
2.1.3.3 -> 41
1.2.1.38 -> 20
4.3.2.1 -> 0
2.3.1.1 -> 65
2.7.2.8 -> 10
6.3.4.5 -> 3
3.5.1.16 -> 16
2.6.1.11 -> 24
```

Average Weight of node:

```
Graph Node -> AvgWeight
2.1.3.3 -> 41
1.2.1.38 -> 20
4.3.2.1 -> 0
2.3.1.1 -> 65
2.7.2.8 -> 10
6.3.4.5 -> 3
3.5.1.16 -> 16
2.6.1.11 -> 24
```

Characteristic path length :

Shortest path distance from node 5 to node 1 is 2
Shortest path distance from node 5 to node 2 is 8
Shortest path distance from node 5 to node 3 is 3
Shortest path distance from node 5 to node 4 is 7
Shortest path distance from node 5 to node 6 is 4