Project #3 – PAD

Connected Components in Hadoop

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Description

Given a graph, the algorithm identifies the **connected components** (Clusters).

We have tried to implement the ***"The Alternating Algorithm"*** proposed in the paper ***Connected Components in MapReduce and Beyond***.

Algorithm 1 The Alternating Algorithm

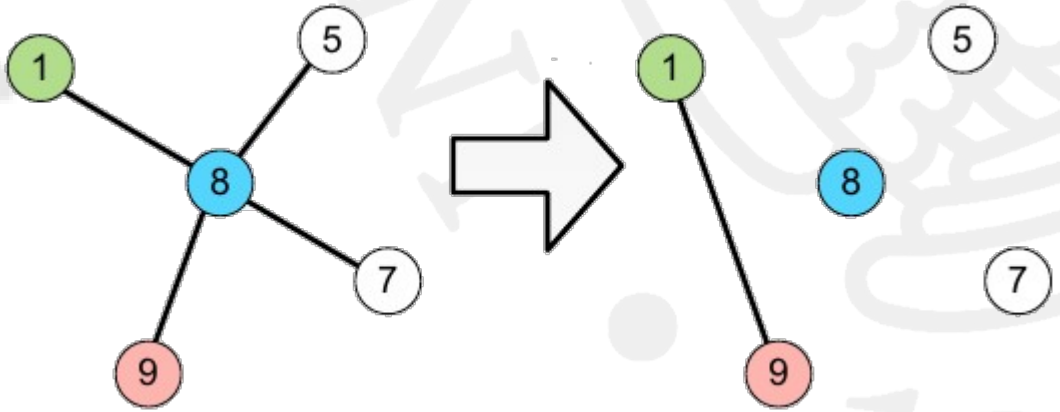
INPUT: Edges (u, v) as a set of key-value pairs ⟨u; v⟩.
INPUT: A unique label ℓ_v for every node v ∈ V.

1: **repeat**
2: Large-Star
3: Small-Star
4: **until** Convergence

Algorithm 2 The Large-Star operation

1: **procedure** MAP(u; v)
2: Emit ⟨u; v⟩
3: Emit ⟨v; u⟩
4: **end procedure**
5: **procedure** REDUCE(u; Γ(u))
6: $m \leftarrow arg\,min_{v \in \Gamma^{+}(u)} \ell_v$
7: Emit ⟨v; m⟩ $\forall v$ where $\ell_v > \ell_u$
8: **end procedure**

Large-Star(v): Connect all strictly **larger** neighbours to the **min** neighbour including **self**.



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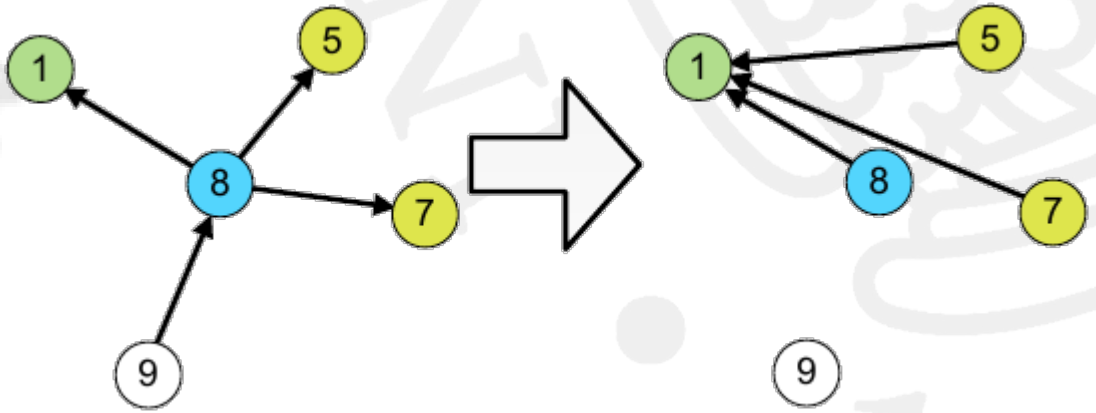
INPUT: A unique label ℓ_v for every node v ∈ V.

```
1: repeat
2:     Large-Star
3:     Small-Star
```

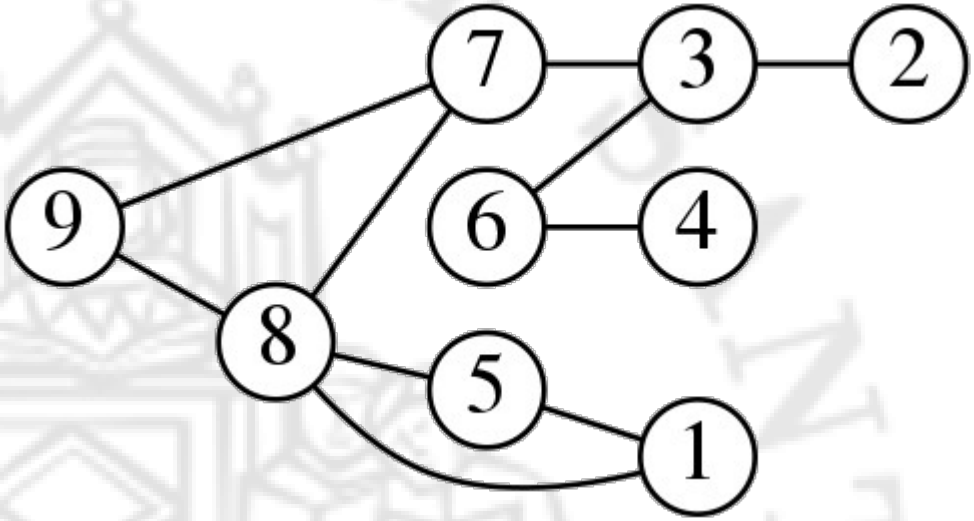
Algorithm 3 The Small-Star operation

```
1: procedure MAP( u; v )
2:     if ℓ_v ≤ ℓ_u then
3:         Emit ⟨u; v⟩
4:     else
5:         Emit ⟨v; u⟩
6:     end if
7: end procedure
8: procedure REDUCE( u; N ⊆ Γ(u) )
9:     m ← arg min_{v∈N∪{u}} ℓ_v
10:    Emit ⟨v; m⟩ ∀v ∈ N
11: end procedure
```

Small-Star(v): Connect all **smaller** neighbours and **self** to the **min** neighbour.



Input



Clique List:

1 5 8
8 9 7
7 3
3 2
3 6
6 4

Adjacency List:

1	5,8
2	3
3	2,6,7
4	6
5	1,8
6	3,4
7	3,8,9
8	1,5,7,9
9	7,8

Initialization Phase

Algorithm 4 Our impler … e Alternating Algorithm

INPUT: G = (V, E) rep … an adjac

INPUT: A unique and p … for eve

1: Initialization_Phase
2: **repeat**
3: Large-Star
4: Small-Star
5: **until** Convergence
6: Termination_Phase
7: Check_Phase

Clique List:

1 5 8
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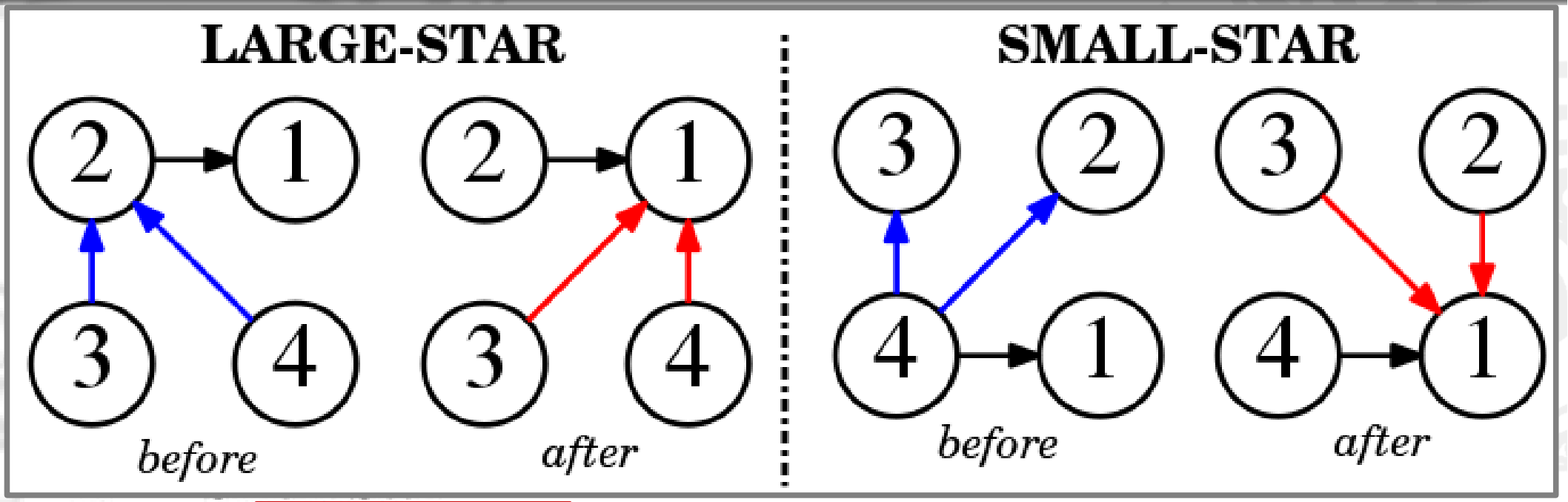
Adjacency List:

1	5,8
2	3
3	2,6,7
4	6
5	1,8
6	3,4
7	3,8,9
8	1,5,7,9
9	7,8

Edge List:

3	2
5	1
6	3
6	4
7	3
8	1
8	5
8	7
9	7
9	8

Convergence



5: **until** Convergence
6: Termination_Phase
7: Check_Phase

If *min* ≠ *currentNode* **then**
#ModifiedEdges ← *#EmittedEdges*

LargeStar.#Changes + SmallStar.#Changes = 0

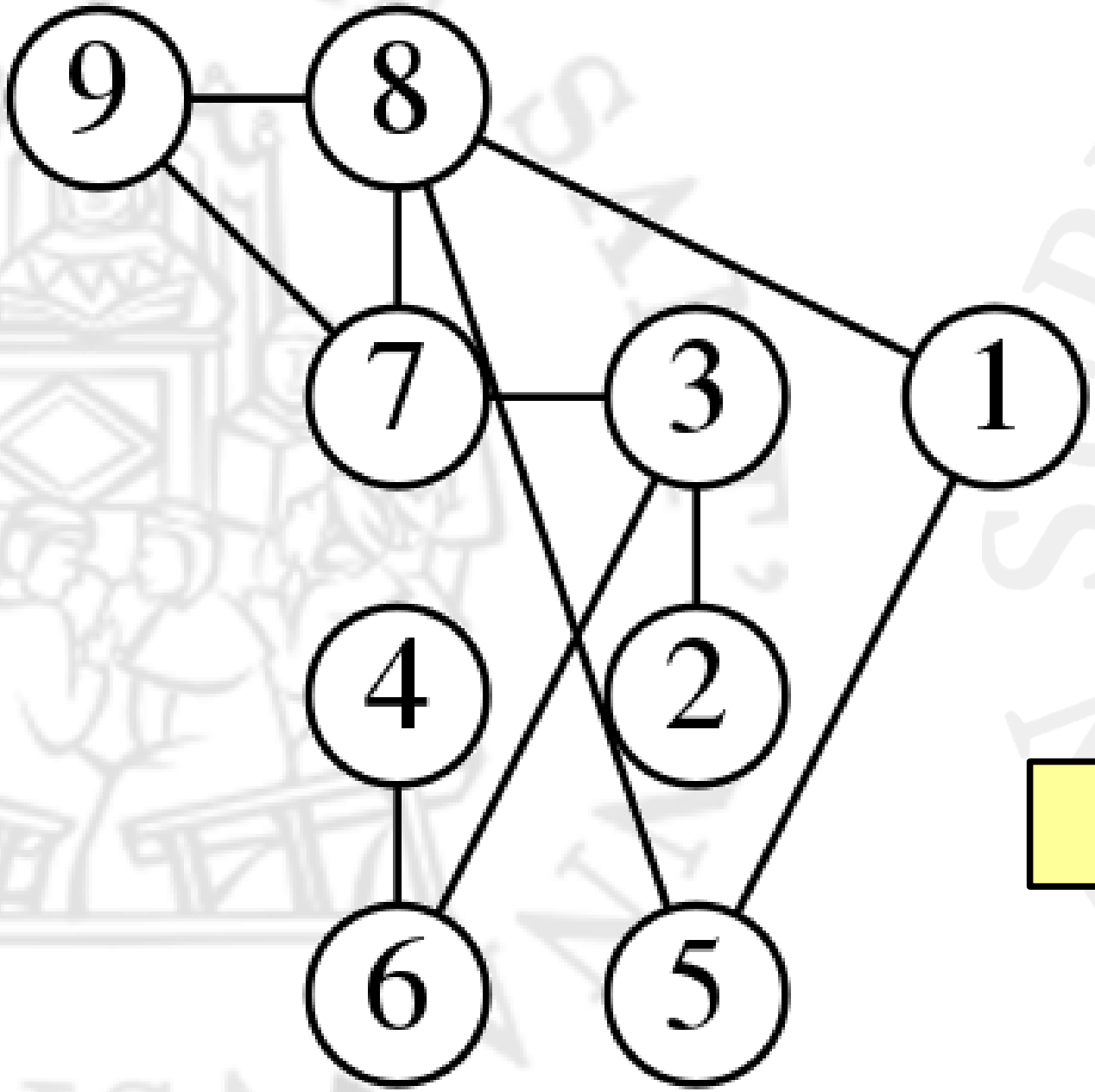
Steps of the Algorithm

Algorithm 4 Our implementation of the Alternating Algorithm

INPUT: G = (V, E) represented with an adjacency/cluster list.
INPUT: A unique and positive label ℓ_v for every node v $\in$ V.

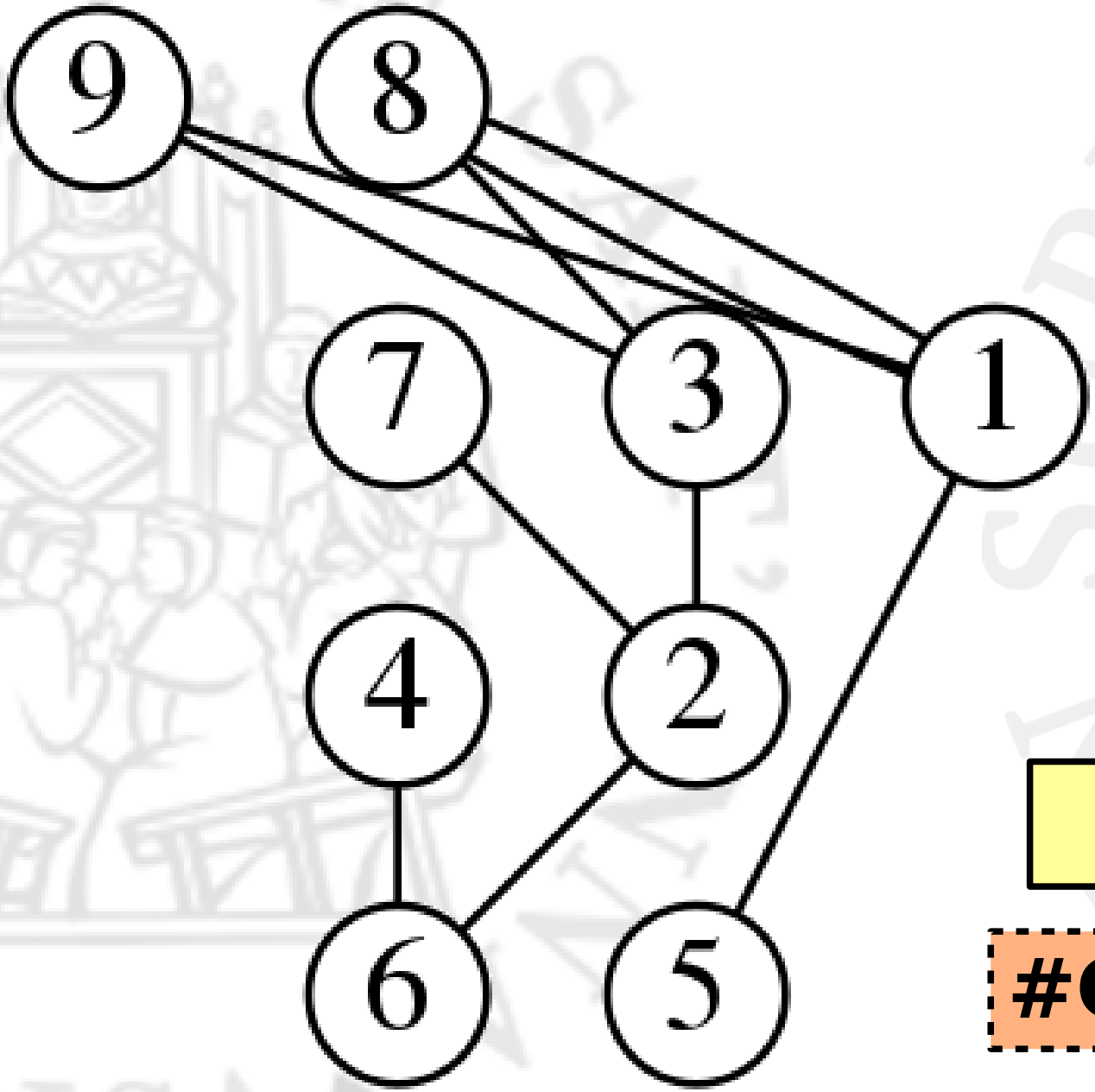
1: Initialization_Phase
2: **repeat**
3: Large-Star
4: Small-Star
5: **until** Convergence
6: Termination_Phase
7: Check_Phase

Steps of the Algorithm



STEP 0

Steps of the Algorithm

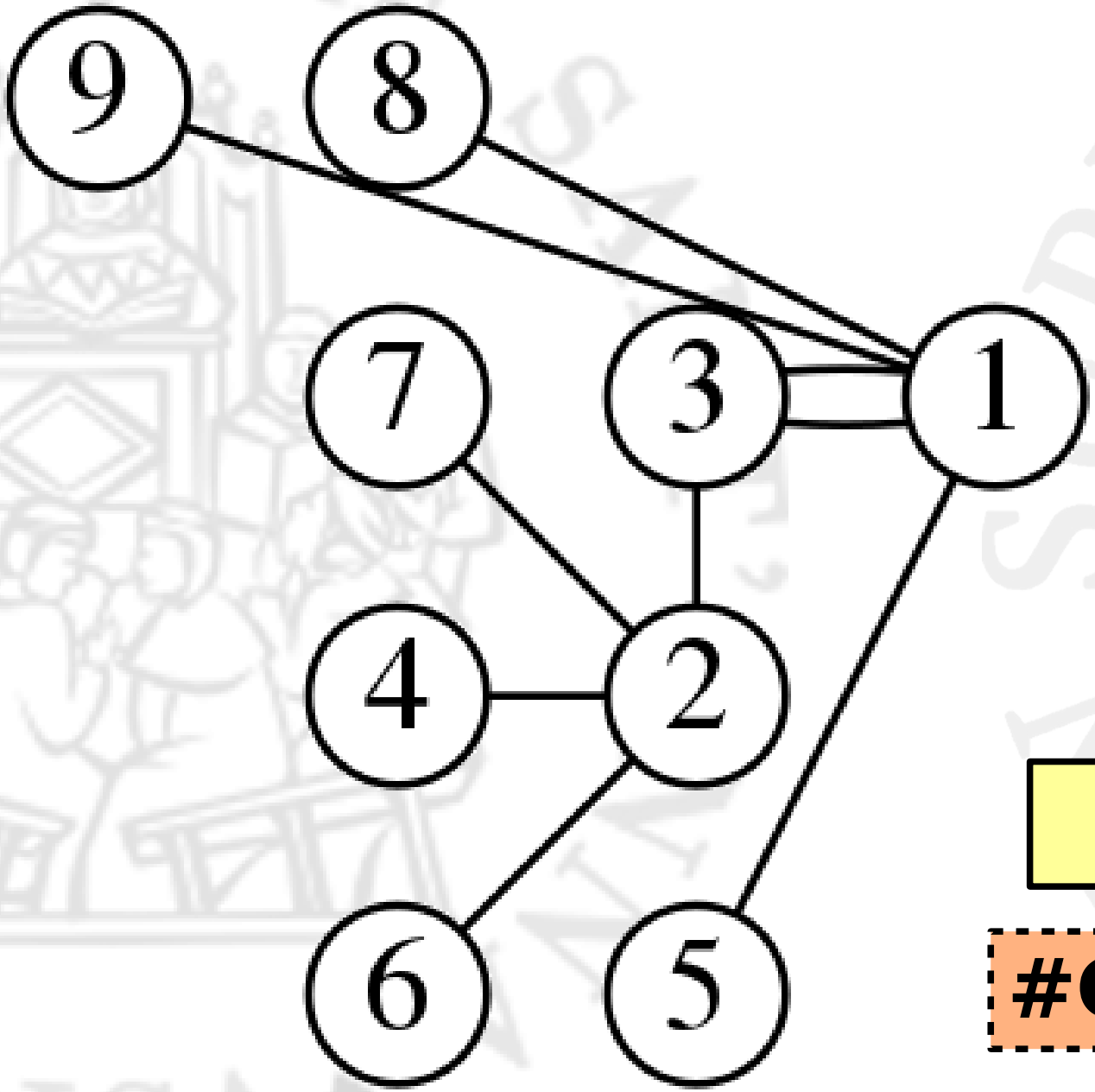


Large-Star

STEP 1

#Changes = 6

Steps of the Algorithm

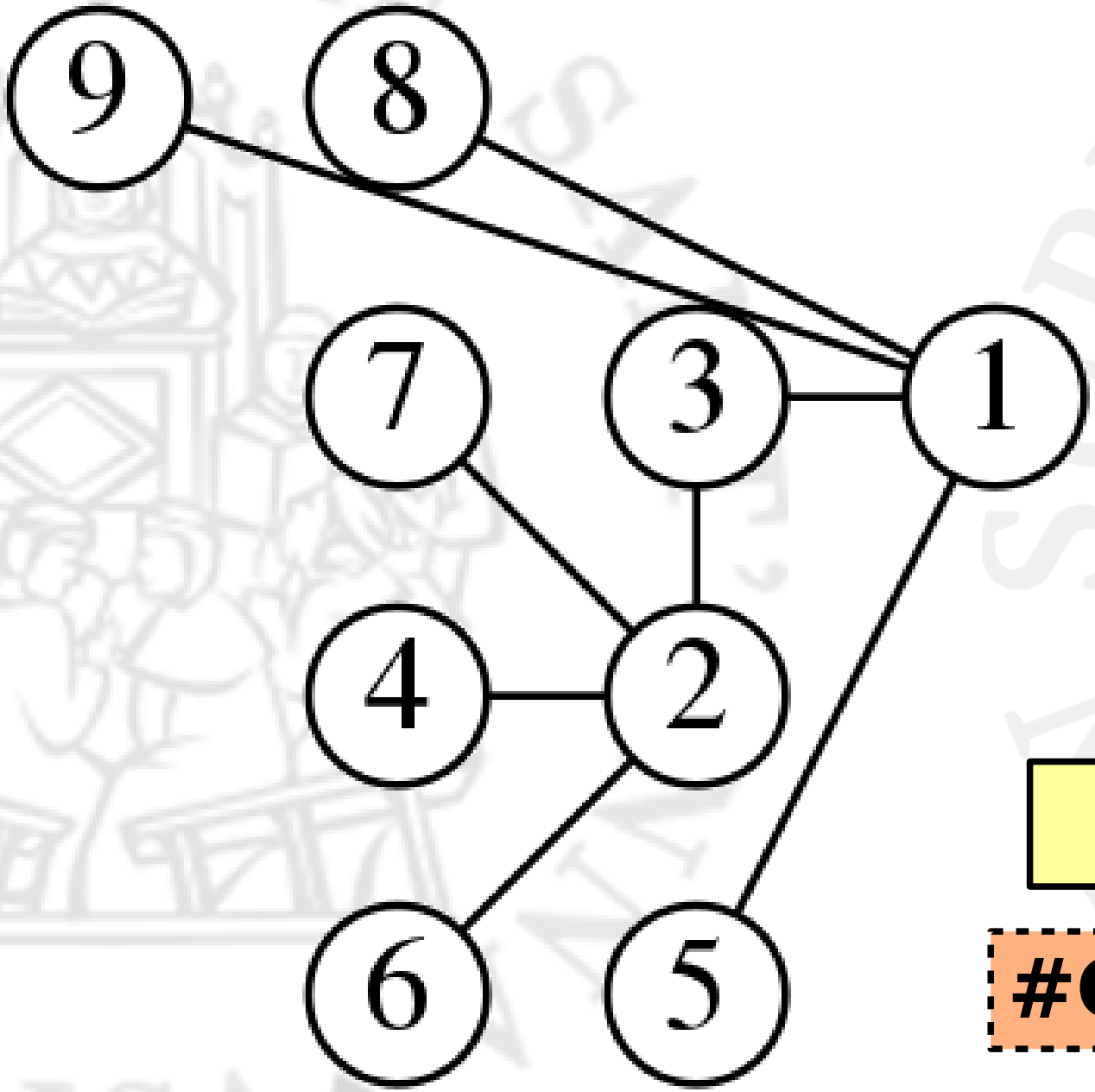


Small-Star

STEP 2

#Changes = 3

Steps of the Algorithm

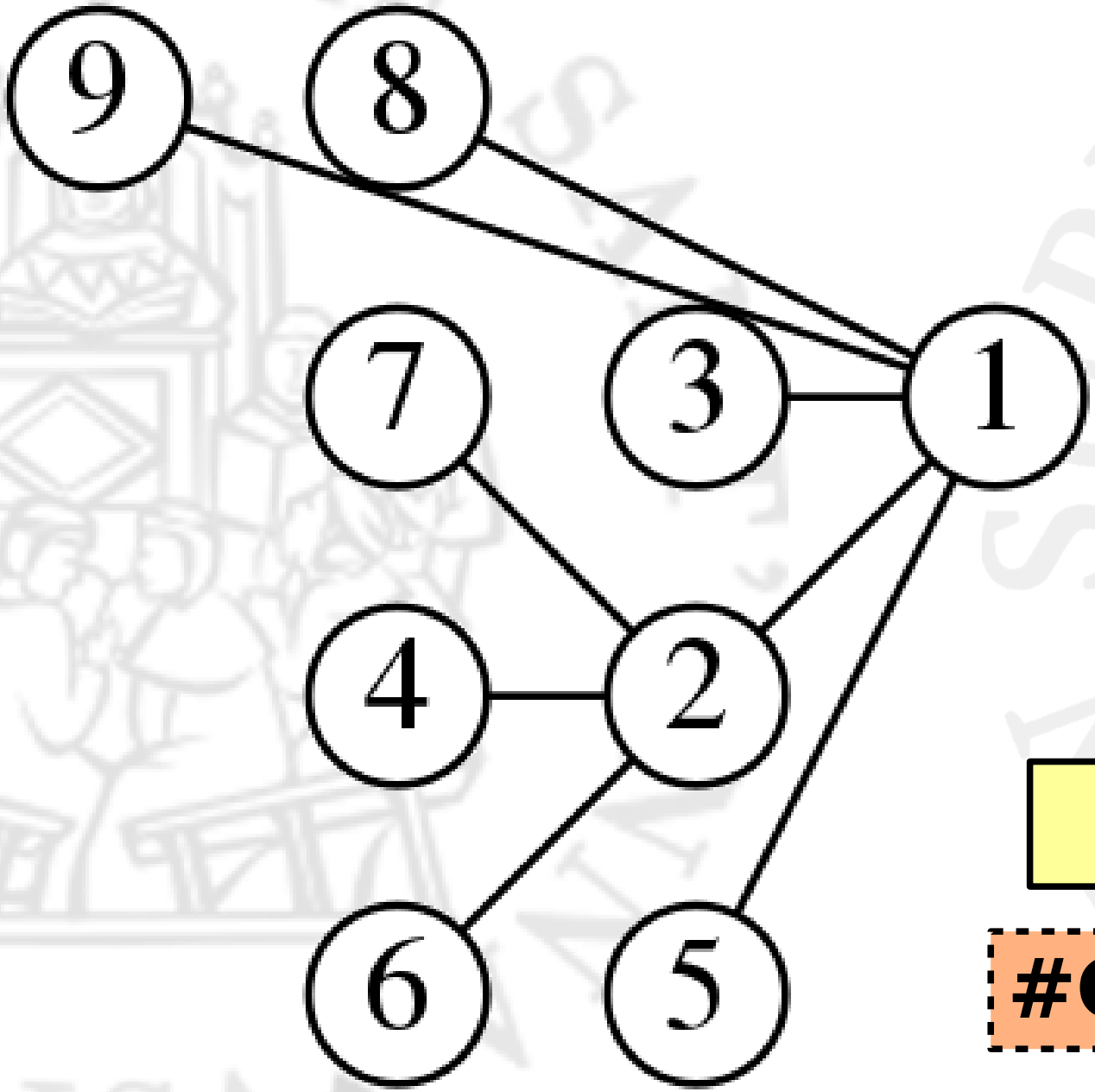


Large-Star

STEP 3

#Changes = 0

Steps of the Algorithm

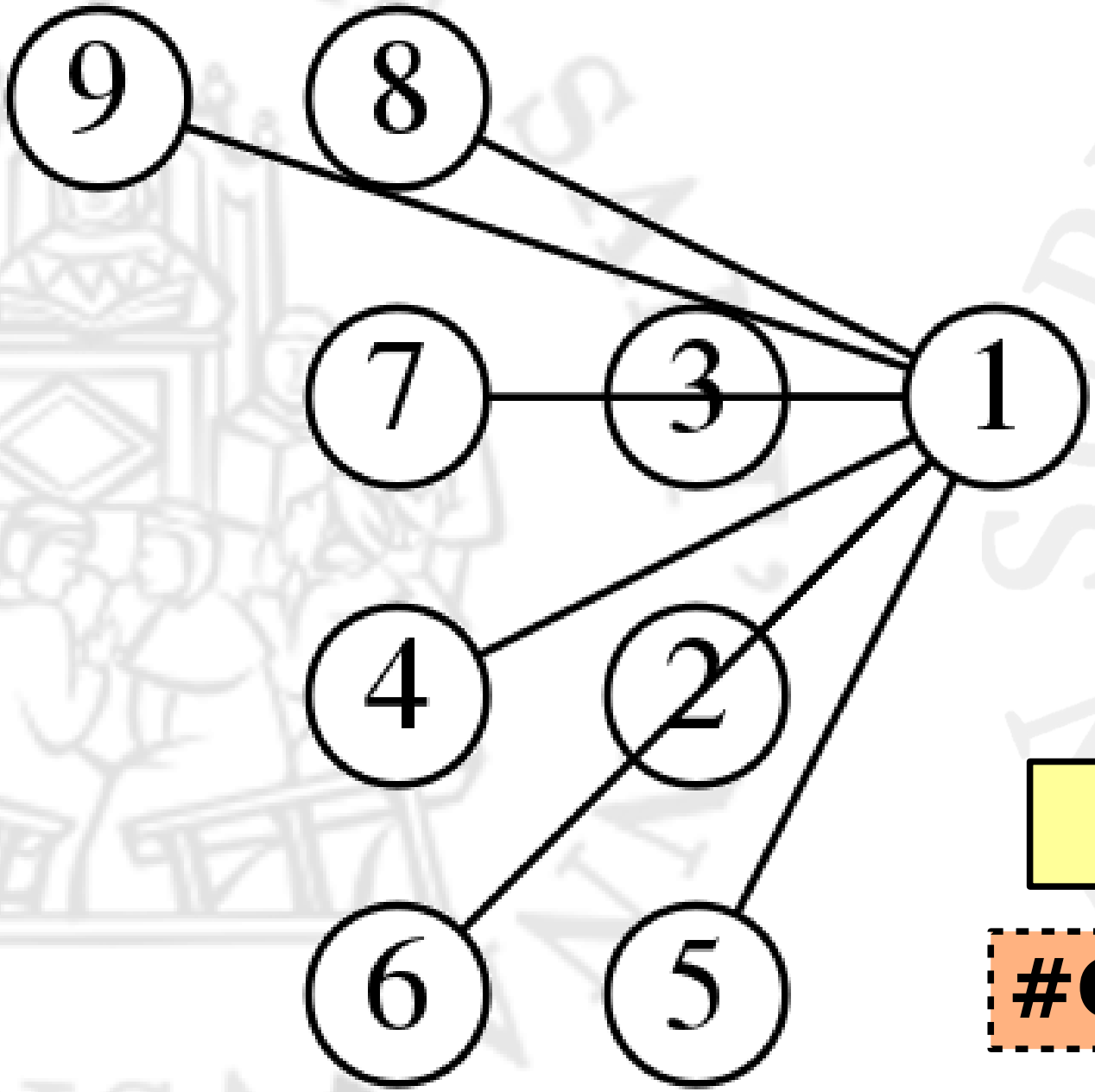


Small-Star

STEP 4

#Changes = 1

Steps of the Algorithm

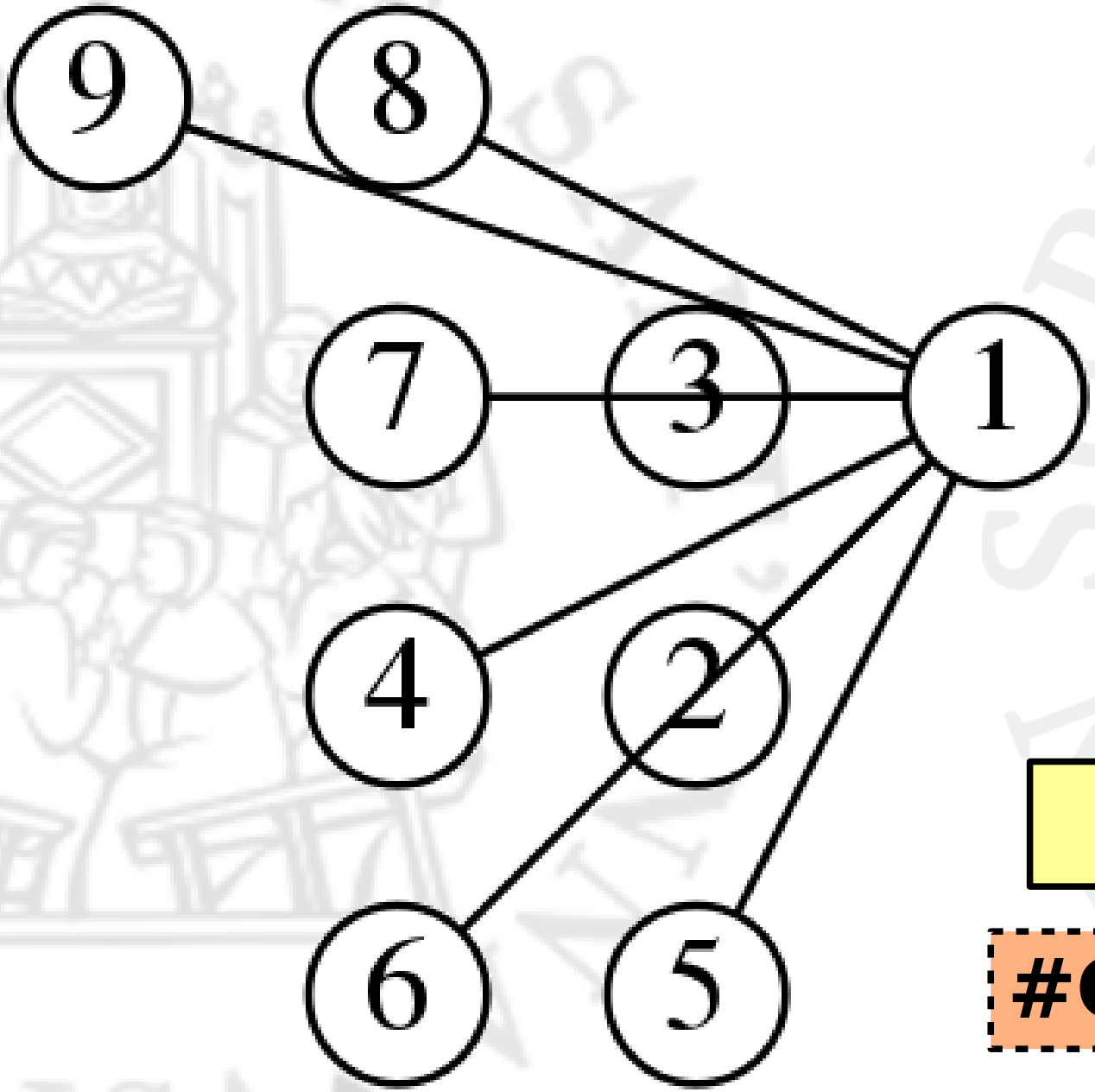


Large-Star

STEP 5

#Changes = 3

Steps of the Algorithm

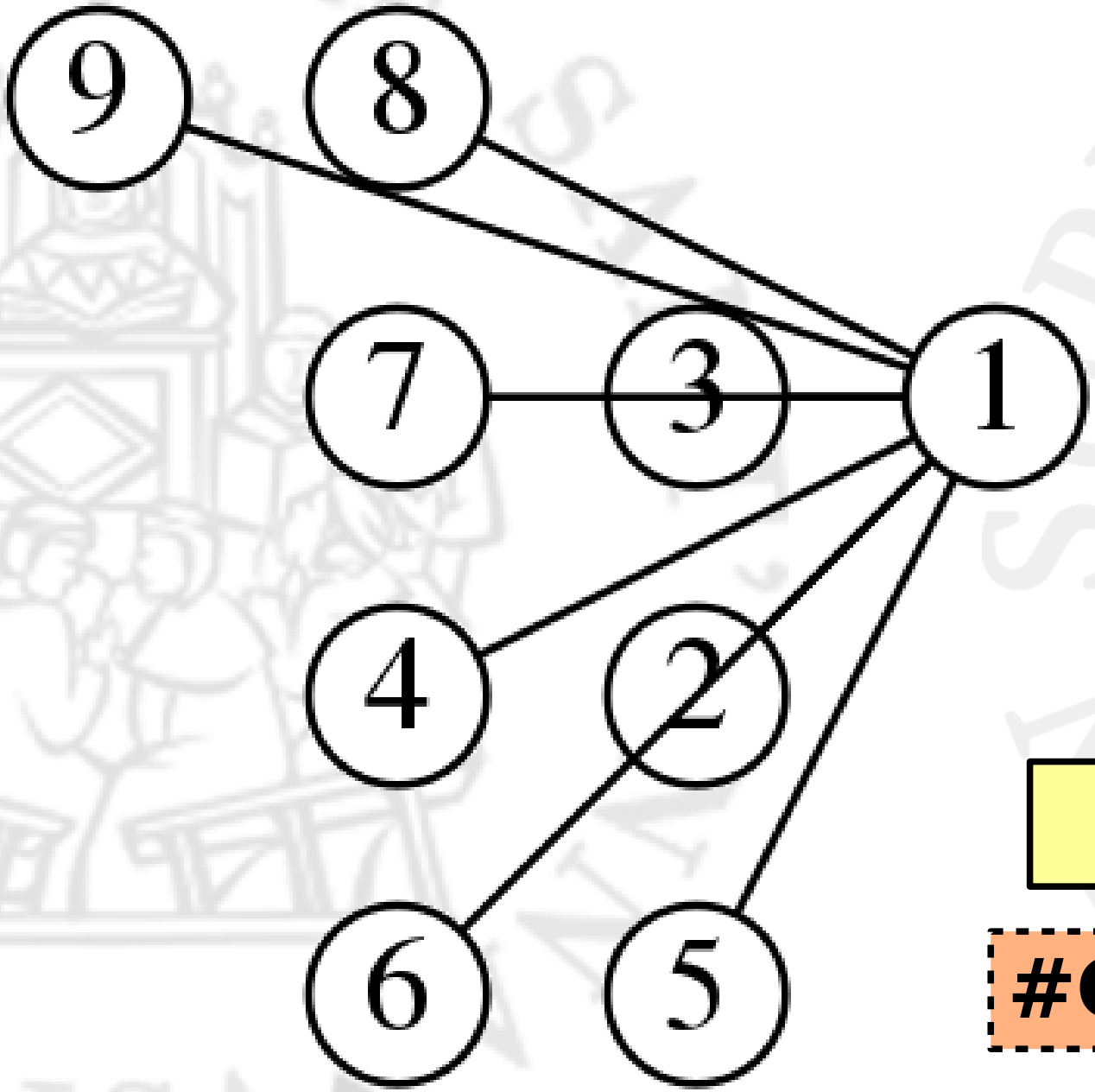


Small-Star

STEP 6

#Changes = 0

Steps of the Algorithm

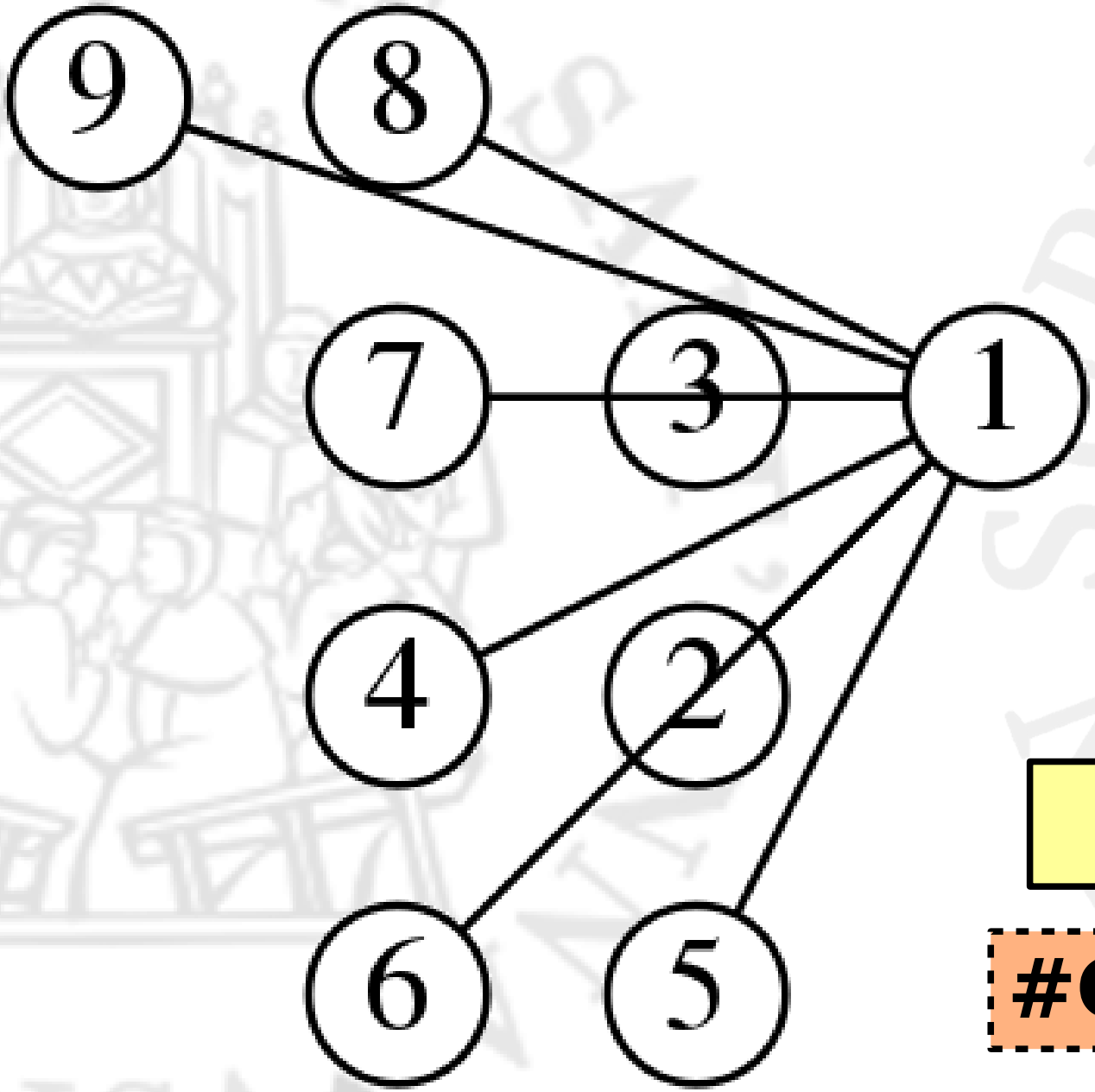


Large-Star

STEP 7

#Changes = 0

Steps of the Algorithm

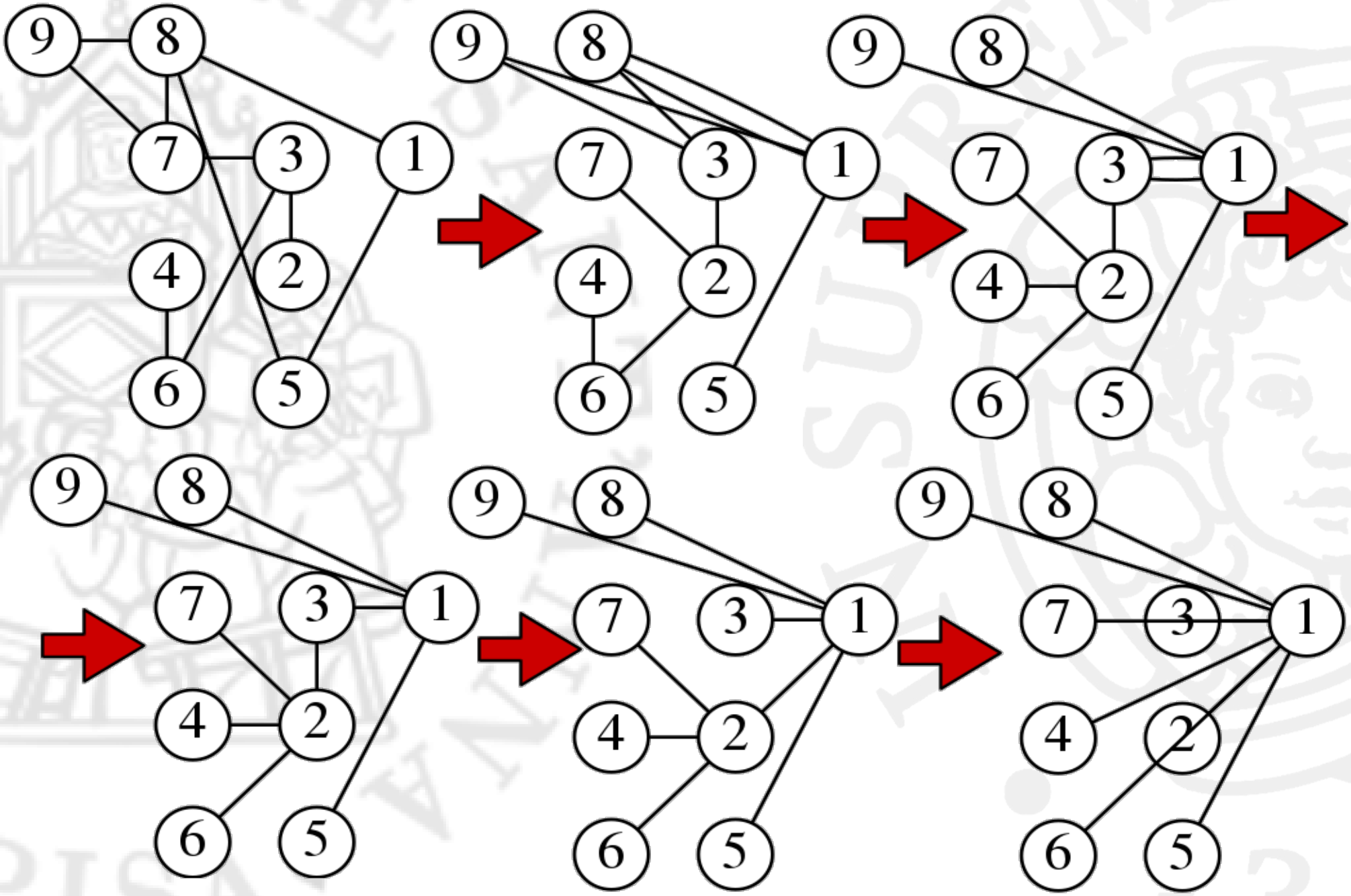


Small-Star

STEP 8

#Changes = 0

Steps of the Algorithm



Termination Phase

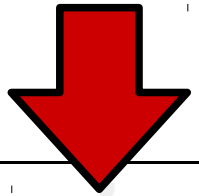
Algorithm 4 Our implementati ting Algorithm

INPUT: G = (V, E) represente ncy/cluster list.
INPUT: A unique and positive node v ∈ V.

1: Initialization_Phase
2: **repeat**
3: Large-Star
4: Small-Star
5: **until** Convergence
6: Termination_Phase
7: Check_Phase

Edge List:

2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1



Star List:

1 2 3 4 5 6 7 8 9

Check Phase

Algorithm 4 Our implementation of the Alternating Algorithm

INPUT: G = (V, E) represented with an adjacency/cluster list.
INPUT: A unique and positive label ℓ_v for every node v $\in$ V.

1: Initialization_Phase
2: **repeat**
3: Large-Star
4: Small-Star
5: **until** Convergence
6: Termination_Phase
7: Check_Phase

In Termination Phase, we ensure to **not store duplicate nodes within a cluster**.

A cluster is **malformed** if one of its node is present in another cluster.

Check that **all nodes are unique**.
If a node is found twice, it is surely present in two different clusters.

Testing Procedures

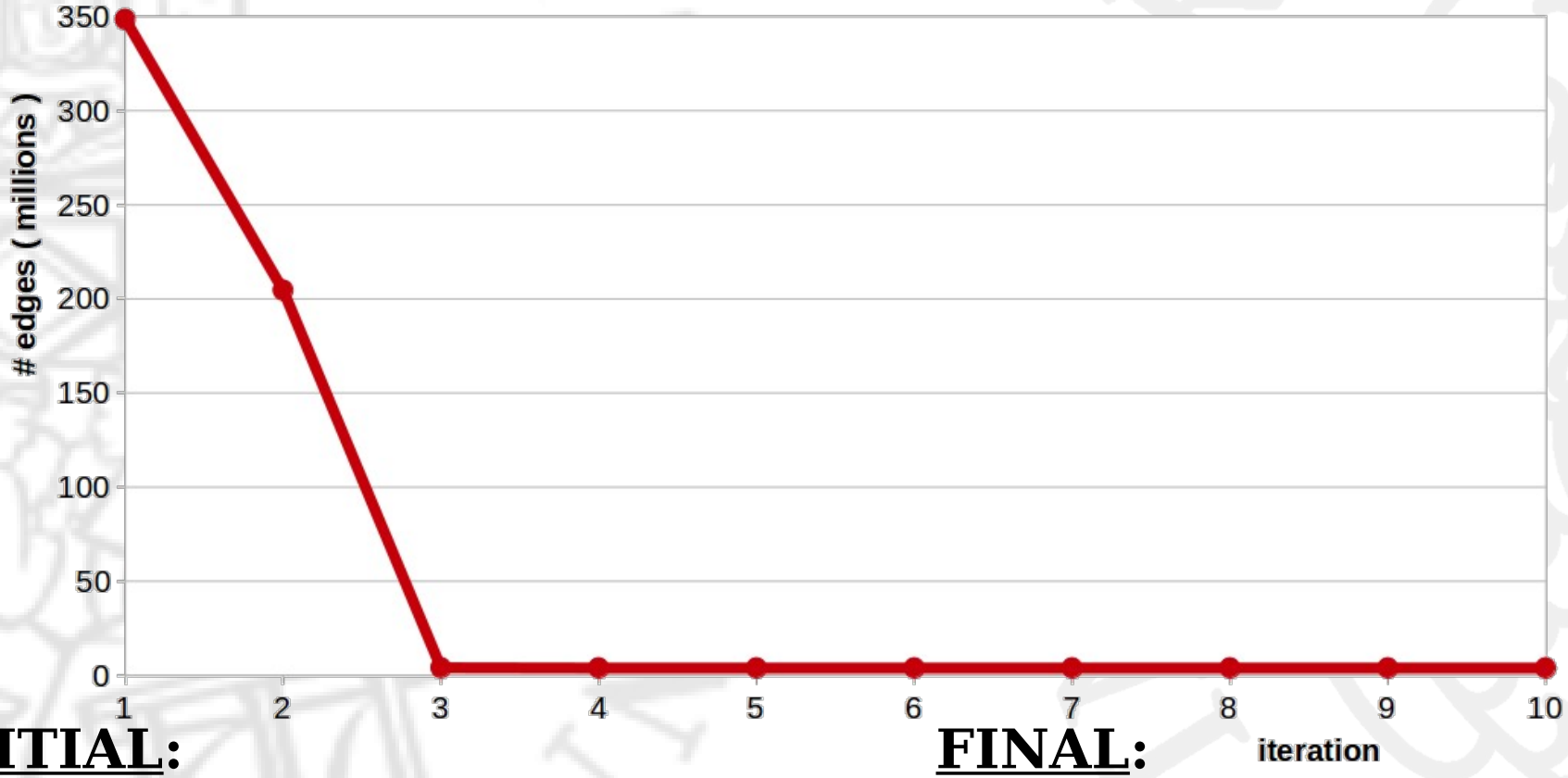
```
Processing input_0.txt.
Added hdfs://localhost:9000/user/draxent/input_0
ConnectedComponents Job started !
ConnectedComponents Job completed !
Input file format: CLIQUES_LIST.
Number of initial nodes: 9.
Number of Cliques: 6.
Number of final nodes: 9.
Number of Clusters: 1.
TestOK: true.
TranslatorDriver Cluster2Text Job started !
TranslatorDriver Cluster2Text Job completed correctly !
16/01/26 11:31:35 INFO util.NativeCodeLoader: Loaded the n
Deleted hdfs://localhost:9000/user/draxent/input_0
Deleted hdfs://localhost:9000/user/draxent/out0
Deleted hdfs://localhost:9000/user/draxent/out0T
No differences between cluster_0.txt and cluster_out_0.txt
Deleted /home/draxent/Github/ConnectedComponents/data/clus
Test on input_0.txt compleated correctly !
Processing input_1.txt.
Added hdfs://localhost:9000/user/draxent/input_1
ConnectedComponents Job started !
ConnectedComponents Job completed !
Input file format: ADJACENCY_LIST.
Number of initial nodes: 20.
Number of Cliques: 0.
Number of final nodes: 20.
Number of Clusters: 5.
TestOK: true.
TranslatorDriver Cluster2Text Job started !
TranslatorDriver Cluster2Text Job completed correctly !
16/01/26 11:34:36 INFO util.NativeCodeLoader: Loaded the n
Deleted hdfs://localhost:9000/user/draxent/input_1
Deleted hdfs://localhost:9000/user/draxent/out1
Deleted hdfs://localhost:9000/user/draxent/out1T
No differences between cluster_1.txt and cluster_out_1.txt
Deleted /home/draxent/Github/ConnectedComponents/data/clus
Test on input_1.txt compleated correctly !
```

```
Processing input_2.txt.
Added hdfs://localhost:9000/user/draxent/input_2
ConnectedComponents Job started !
ConnectedComponents Job completed !
Input file format: ADJACENCY_LIST.
Number of initial nodes: 25.
Number of Cliques: 0.
Number of final nodes: 25.
Number of Clusters: 1.
TestOK: true.
TranslatorDriver Cluster2Text Job started !
TranslatorDriver Cluster2Text Job completed correctly !
16/01/26 11:38:43 INFO util.NativeCodeLoader: Loaded the n
Deleted hdfs://localhost:9000/user/draxent/input_2
Deleted hdfs://localhost:9000/user/draxent/out2
Deleted hdfs://localhost:9000/user/draxent/out2T
No differences between cluster_2.txt and cluster_out_2.txt
Deleted /home/draxent/Github/ConnectedComponents/data/clus
Test on input_2.txt compleated correctly !
Processing input_3.txt.
Added hdfs://localhost:9000/user/draxent/input_3
ConnectedComponents Job started !
ConnectedComponents Job completed !
Input file format: CLIQUES_LIST.
Number of initial nodes: 98.
Number of Cliques: 67.
Number of final nodes: 98.
Number of Clusters: 6.
TestOK: true.
TranslatorDriver Cluster2Text Job started !
TranslatorDriver Cluster2Text Job completed correctly !
16/01/26 11:42:56 INFO util.NativeCodeLoader: Loaded the n
Deleted hdfs://localhost:9000/user/draxent/input_3
Deleted hdfs://localhost:9000/user/draxent/out3
Deleted hdfs://localhost:9000/user/draxent/out3T
No differences between cluster_3.txt and cluster_out_3.txt
Deleted /home/draxent/Github/ConnectedComponents/data/clus
Test on input_3.txt compleated correctly !
```

Experimental Evaluation

Clique List file:

- **Size of 73.7MB**
- **#Iterations = 10**



INITIAL:

- **#Nodes = 5,869,938**
- **#Clique = three millions**
- **#Edges = 348,528,515**

FINAL:

- **#Nodes = 5,869,938**
- **#Star = 2,039,304**
- **#Edges = 3,830,634**