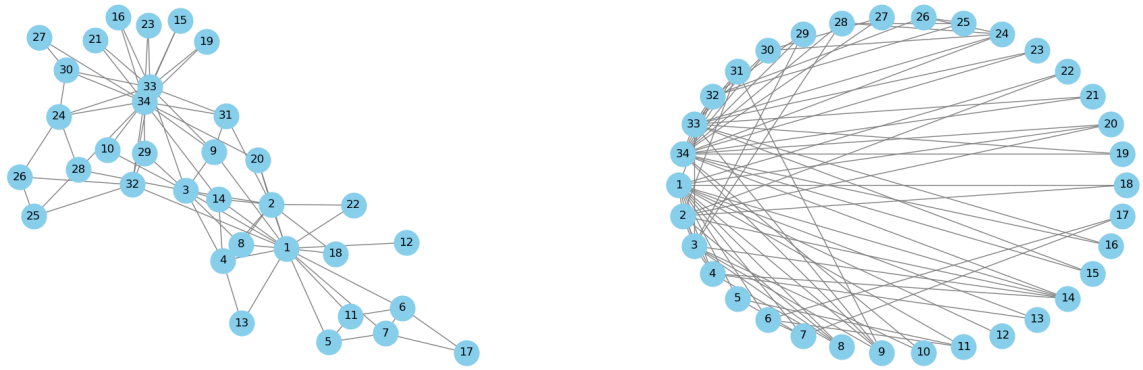
Complex Systems

CS2024/problem_5.pdf

Result

Task 1

For "https://websites.umich.edu/ mejn/netdata/" - Zachary's karate club (karate.gml)



(a) Spring layout

(b) Shell layout

Figure 1: Nodes: 34, Edges: 78

Task 2

(a) Network layout

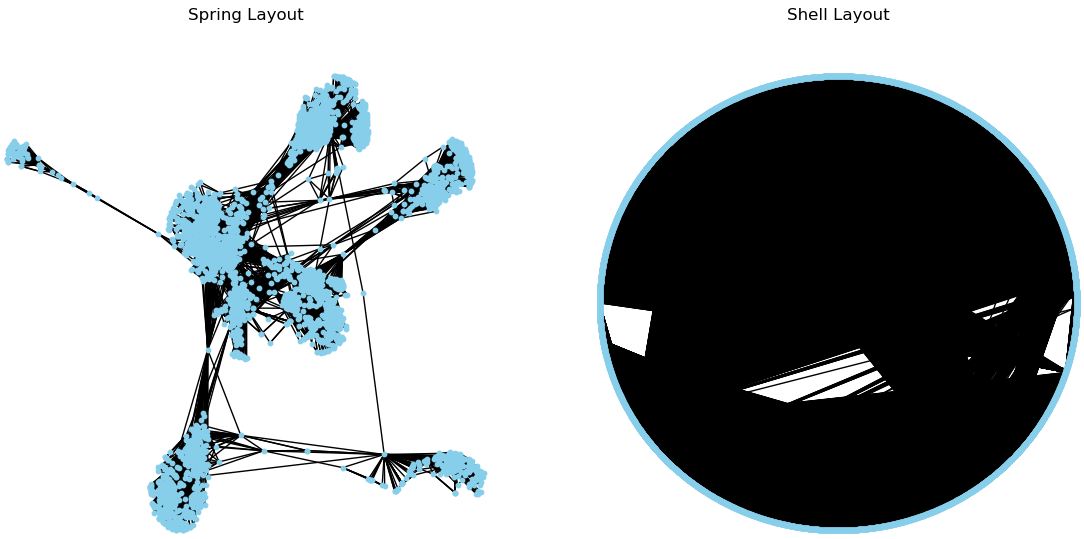


Figure 2: ego-Facebook Network Layout

(b) Degree Distribution

The degree of a node in a graph refers to the number of edges that are incident to it. It is evident that many nodes are connected to fewer nodes compared to others.

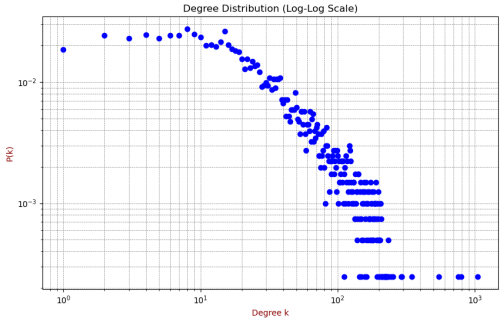


Figure 3: Average degree < k >: 43.69101262688784

(c) Distribution of clustering coefficients and an average clustering coefficient.

The clustering coefficient indicates the likelihood that a node's neighbors are connected to each other, forming a triangle. It quantifies the local connectivity of the node.

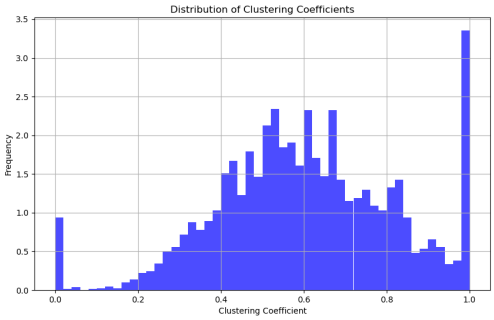


Figure 4: Average Clustering Coefficient: 0.6055467186200862

(d) Distribution of the shortest paths, the diameter and the average path length

The shortest path is the fewest edges between nodes. A histogram shows their counts, the diameter is the longest shortest path, and the average path length is their mean.

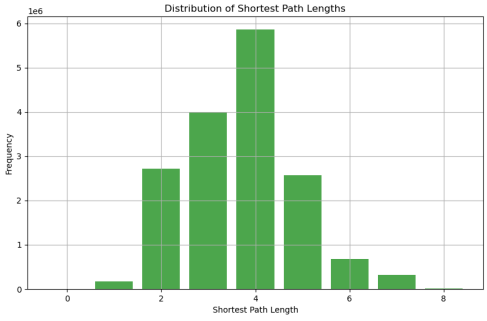


Figure 5: Average Path Length: 3.691592636562027, Diameter: 8

Task 3

(a) Erdos-Renyi model G(N,L) $< k > = 2L/N$

Listing 1: Erdos-Renyi model

```python
def erdos_renyi(N, L):
    G = nx.Graph()
    G.add_nodes_from(range(N))

    edges = set()
    while len(edges) < L:
        u = random.randint(0, N - 1)
        v = random.randint(0, N - 1)
        if u != v and (u, v) not in edges and (v, u) not in edges:
            edges.add((u, v))

    G.add_edges_from(edges)
    return G
```

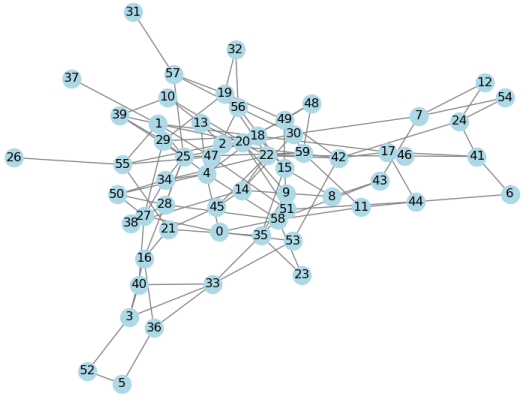


Figure 6: N = 60, L = 120

Table 1: Graph Statistics: G(N, L)

Statistic	**Value**
Average Degree	6.0
Average Clustering Coefficient	0.0525
Average Path Length	2.706
Diameter	5

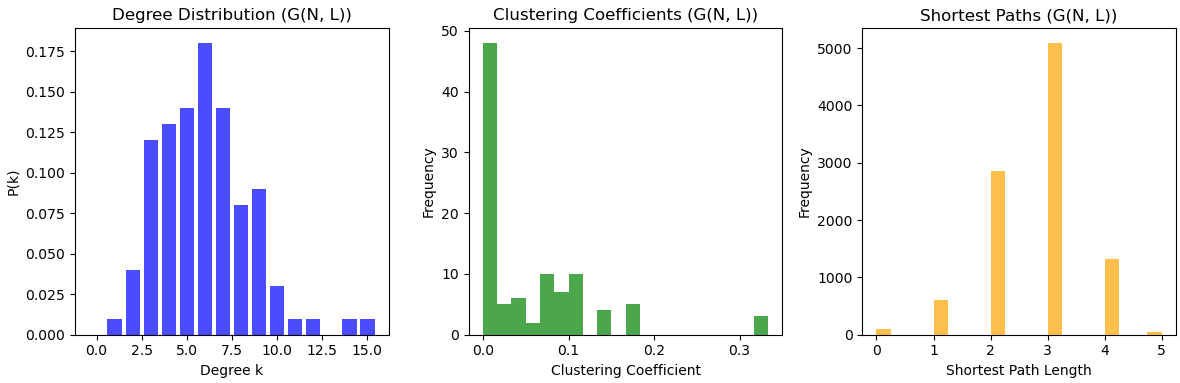


Figure 7: N = 100, L = 300

(b) Erdos-Renyi-Gilbert model G(N,p) $< k > = p(n-1)$

Listing 2: Erdos-Renyi model

```
# Parameters
N = 60  # Number of nodes
p = 0.25  # Probability of edge creation
G_Np = nx.erdos_renyi_graph(N, p)

# Plotting
plt.figure(figsize=(8, 6))
nx.draw(G_Np, with_labels=True, node_color='lightgreen', edge_color='gray')
plt.title(f"Erdos-Renyi-Gilbert Model G(N={N}, p={p})")
plt.savefig("erdos_renyi_gilbert_model.png")
plt.show()
```

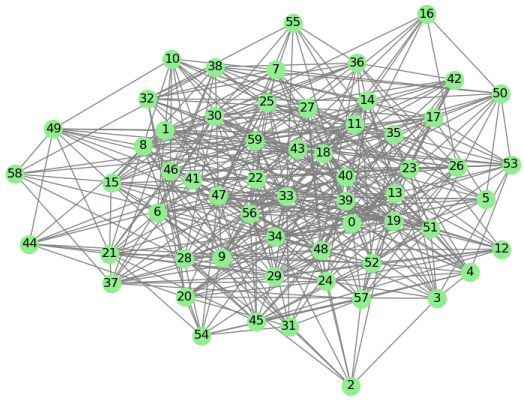


Figure 8: N = 60, p = 0.25

Table 2: Graph Statistics: G(N, p)

Statistic	**Value**
Average Degree	6.34
Average Clustering Coefficient	0.0796
Average Path Length	2.6372
Diameter	5

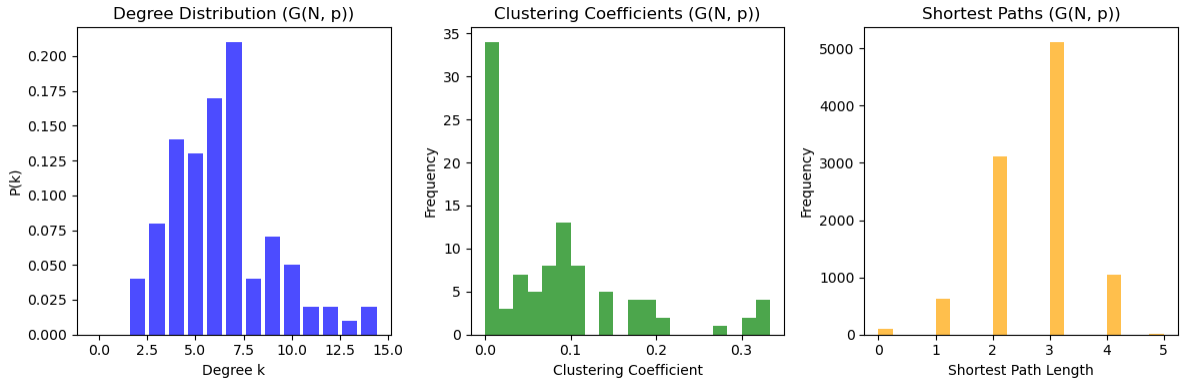


Figure 9: N = 100, p = 0.25

(c) Watts-Strogatz model WS(N,k,β) $< k > = 2K/N < k > = k$, $0 < \beta < 1$

Listing 3: Erdos-Renyi model

```
# Parameters
N = 20  # Number of nodes
k = 4   # Each node is connected to k neighbors
beta = 0.3  # Rewiring probability
G_WS = nx.watts_strogatz_graph(N, k, beta)

# Plotting
plt.figure(figsize=(8, 6))
nx.draw_circular(G_WS, with_labels=True, node_color='lightcoral', edge_color='
    gray')
plt.title(f"Watts and Strogatz Model WS(N={N}, k={k}, beta={beta})")
plt.savefig('WS.png')
plt.show()
```

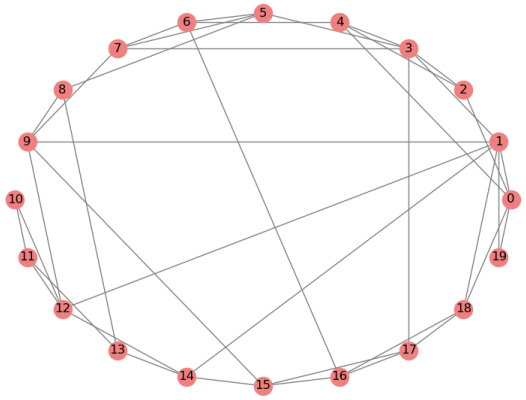


Figure 10: N = 20, k = 4, $\beta = 0.3$

Table 3: Graph Statistics: WS(N, k, β)

Statistic	**Value**
Average Degree	6.0
Average Clustering Coefficient	0.2203
Average Path Length	2.9694
Diameter	5

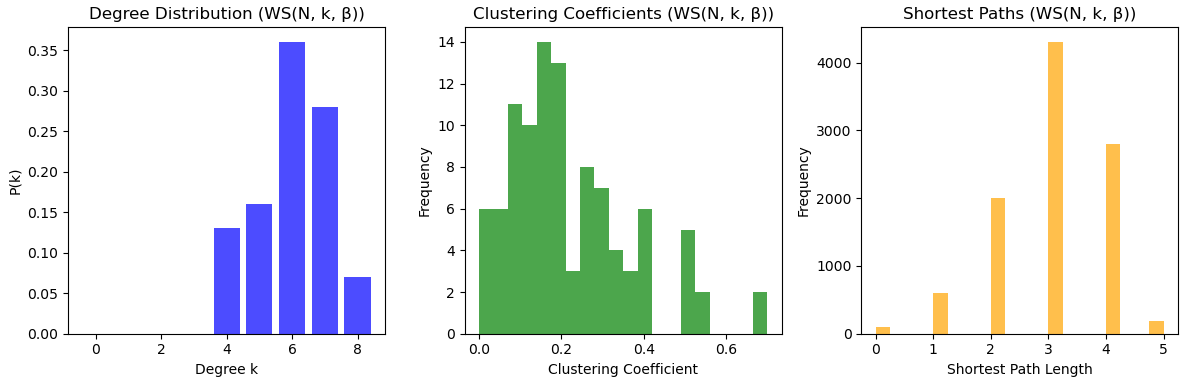


Figure 11: Analysis N = 100, k = 7, $\beta = 0.3$