lab-8-22mcb1002

April 30, 2023

[13]:
```
import pandas as pd
import numpy as np
import networkx as nx
from math import log
import matplotlib.pyplot as plt
import matplotlib.patches as mpatches
import plotly.express as px
```

[9]:
```
nodes = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,
         20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33]
edges = [(0, 1), (0, 2), (0, 3), (0, 4), (0, 5), (0, 6), (0, 7), (0, 8),
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         (28, 31), (28, 33), (29, 32), (29, 33), (30, 32), (30, 33), (31, 32),
         (31, 33), (32, 33)]
G = nx.Graph()
G.add_nodes_from(nodes)
G.add_edges_from(edges)

nx.draw(G, with_labels = True, node_size = 1200, node_color = '#90ee90')
plt.show()
```

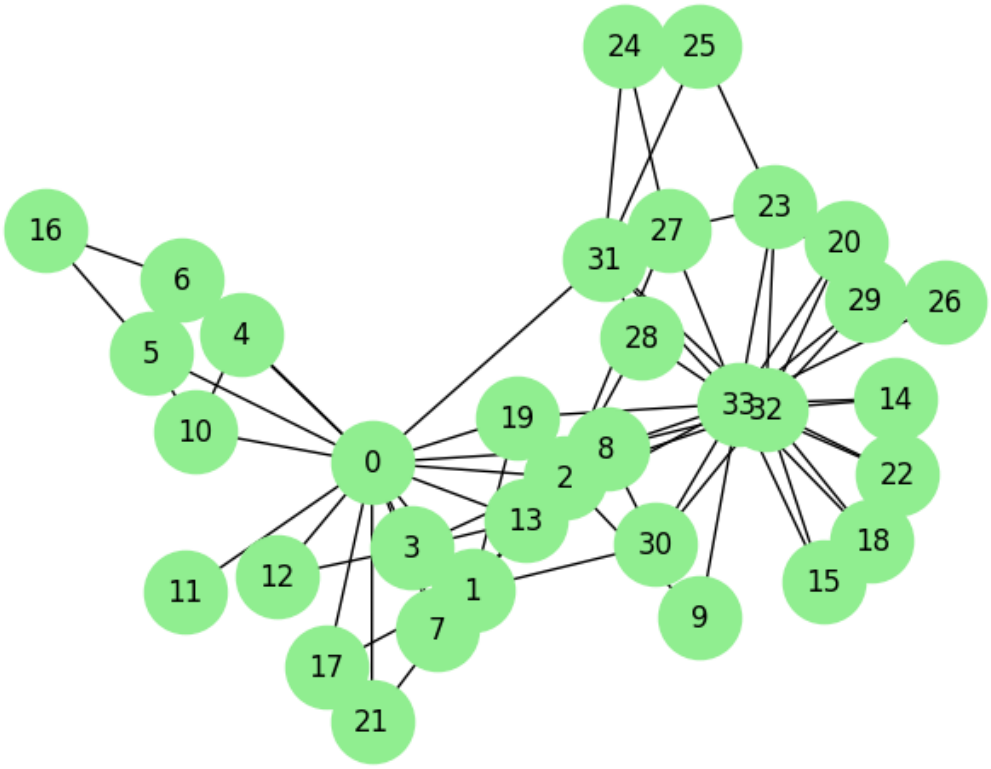

i) Node degree of network

[5]:
```
degrees = dict(G.degree())
for node, degree in degrees.items():
    print("Node", node, "has degree", degree)
```

```
Node 0 has degree 16
Node 1 has degree 9
Node 2 has degree 10
Node 3 has degree 6
Node 4 has degree 3
Node 5 has degree 4
Node 6 has degree 4
Node 7 has degree 4
Node 8 has degree 5
Node 9 has degree 2
Node 10 has degree 3
Node 11 has degree 1
Node 12 has degree 2
Node 13 has degree 5
Node 14 has degree 2
```

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Node 15 has degree 2
Node 16 has degree 2
Node 17 has degree 2
Node 18 has degree 2
Node 19 has degree 3
Node 20 has degree 2
Node 21 has degree 2
Node 22 has degree 2
Node 23 has degree 5
Node 24 has degree 3
Node 25 has degree 3
Node 26 has degree 2
Node 27 has degree 4
Node 28 has degree 3
Node 29 has degree 4
Node 30 has degree 4
Node 31 has degree 6
Node 32 has degree 12
Node 33 has degree 17
```

ii) Edges which will be formed in future

[15]:
```
# Using Adamic-Adar algorithm
future_edges = []
for u, v in nx.non_edges(G):
    score = sum(1 / log(G.degree(w)) for w in nx.common_neighbors(G, u, v))
    future_edges.append((u, v, {'score': score}))
sorted_edges = sorted(future_edges, key=lambda x: x[2]['score'], reverse = True)
future_edges
```

[15]:
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(20, 24, {'score': 0}),
(20, 25, {'score': 0}),
(20, 26, {'score': 0.35295612386476116}),
(20, 27, {'score': 0.35295612386476116}),
(20, 28, {'score': 0.35295612386476116}),
(20, 29, {'score': 0.7553857282466059}),
(20, 30, {'score': 0.7553857282466059}),
(20, 31, {'score': 0.7553857282466059}),
(21, 32, {'score': 0}),
(21, 33, {'score': 0}),
(21, 22, {'score': 0}),
(21, 23, {'score': 0}),
(21, 24, {'score': 0}),
(21, 25, {'score': 0}),
(21, 26, {'score': 0}),
(21, 27, {'score': 0}),
(21, 28, {'score': 0}),
(21, 29, {'score': 0}),
(21, 30, {'score': 0.45511961331341866}),
(21, 31, {'score': 0.36067376022224085}),
(22, 23, {'score': 0.7553857282466059}),
```

```
(22, 24, {'score': 0}),
(22, 25, {'score': 0}),
(22, 26, {'score': 0.35295612386476116}),
(22, 27, {'score': 0.35295612386476116}),
(22, 28, {'score': 0.35295612386476116}),
(22, 29, {'score': 0.7553857282466059}),
(22, 30, {'score': 0.7553857282466059}),
(22, 31, {'score': 0.7553857282466059}),
(23, 24, {'score': 1.631586747071319}),
(23, 26, {'score': 1.0743036443092429}),
(23, 28, {'score': 0.35295612386476116}),
(23, 30, {'score': 0.7553857282466059}),
(23, 31, {'score': 1.6656249548734432}),
(24, 32, {'score': 0.5581106265512472}),
(24, 33, {'score': 1.279458146995729}),
(24, 26, {'score': 0}),
(24, 28, {'score': 0.5581106265512472}),
(24, 29, {'score': 0}),
(24, 30, {'score': 0}),
(25, 32, {'score': 1.179445561110859}),
(25, 33, {'score': 1.179445561110859}),
(25, 26, {'score': 0}),
(25, 27, {'score': 1.531574161186449}),
(25, 28, {'score': 0.5581106265512472}),
(25, 29, {'score': 0.6213349345596119}),
(25, 30, {'score': 0}),
(26, 32, {'score': 1.0743036443092429}),
(26, 27, {'score': 0.35295612386476116}),
(26, 28, {'score': 0.35295612386476116}),
(26, 30, {'score': 0.35295612386476116}),
(26, 31, {'score': 0.35295612386476116}),
(27, 32, {'score': 1.4085855403276248}),
(27, 28, {'score': 0.7872506057680129}),
(27, 29, {'score': 0.974291058424373}),
(27, 30, {'score': 0.35295612386476116}),
(27, 31, {'score': 1.2631953504915985}),
(28, 32, {'score': 1.34536123231926}),
(28, 29, {'score': 0.35295612386476116}),
(28, 30, {'score': 0.35295612386476116}),
(29, 30, {'score': 0.7553857282466059}),
(29, 31, {'score': 0.7553857282466059}),
(30, 31, {'score': 0.7553857282466059})]
```

iii) Common neighbour measure

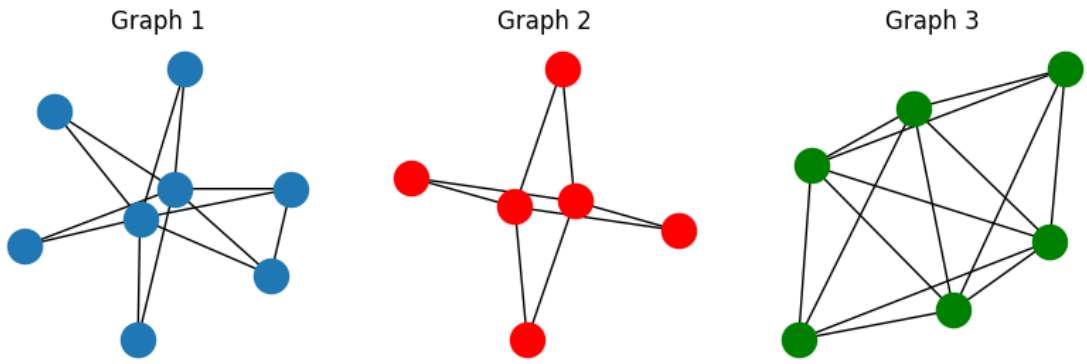
[18]:
```
def common_neighbor_measure(G, u, v):
    neighbors_u = set(G.neighbors(u))
```

```
    neighbors_v = set(G.neighbors(v))
    common_neighbors = neighbors_u.intersection(neighbors_v)
    return len(common_neighbors)
common_neighbor_measure(G, 6, 10)
```

[18]: 3

iv) Subgraph containing '2 nodes' common neighbors

[27]:
```
common_neighbors1 = list(nx.common_neighbors(G, 2, 33))
subgraph1 = G.subgraph(common_neighbors1 + [2, 33])
common_neighbors2 = list(nx.common_neighbors(G, 0, 33))
subgraph2 = G.subgraph(common_neighbors2 + [0, 33])
common_neighbors3 = list(nx.common_neighbors(G, 7, 13))
subgraph3 = G.subgraph(common_neighbors3 + [7, 13])

fig, axs = plt.subplots(1, 3, figsize = (10, 3))
nx.draw(subgraph1, ax=axs[0])
nx.draw(subgraph2, ax=axs[1], node_color = 'red')
nx.draw(subgraph3, ax=axs[2], node_color = 'green')

axs[0].set_title('Graph 1')
axs[1].set_title('Graph 2')
axs[2].set_title('Graph 3')

plt.show()
```



v) Jaccard Coefficient

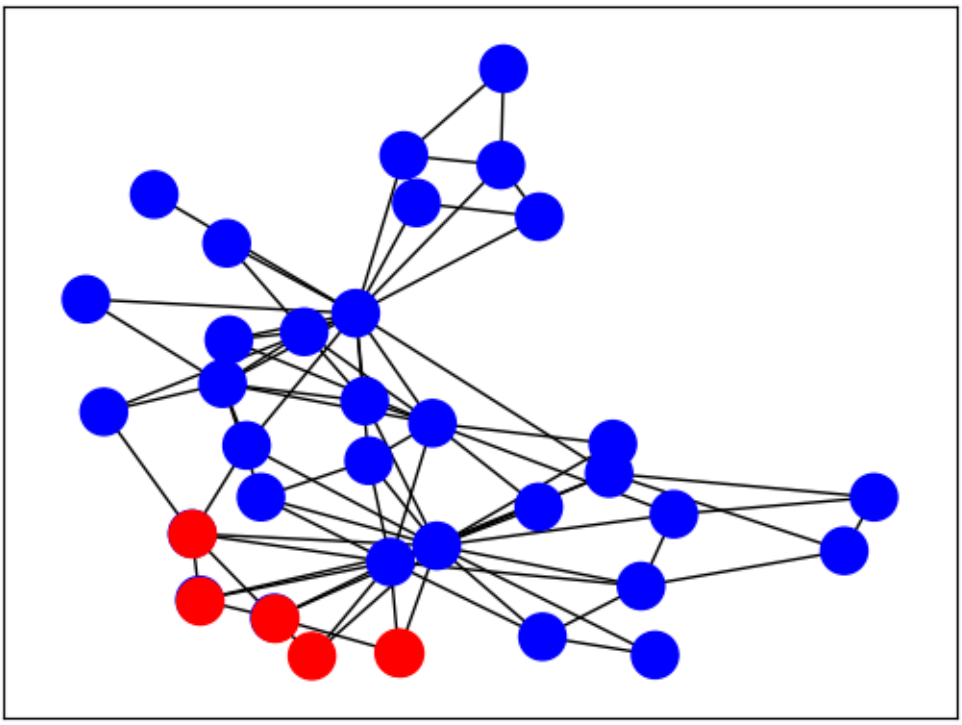
[43]:
```
G.add_edges_from([(14, 15), (14, 18), (14, 20), (14, 22), (15, 18)])
jaccard = list(nx.jaccard_coefficient(G))
df_jaccard = pd.DataFrame(jaccard, columns=['source', 'target',␣
 ↪'jaccard_coeff'])
df_jaccard = df_jaccard.sort_values('jaccard_coeff', ascending = False)
```

```
print(df_jaccard)
```

```
     source  target  jaccard_coeff
411      20      22           1.00
174       7      13           0.80
146       6      10           0.75
91        4       5           0.75
399      19      21           0.75
..      ...     ...            ...
292      12      20           0.00
116       4      32           0.00
294      12      22           0.00
295      12      23           0.00
331      14      25           0.00

[476 rows x 3 columns]
```

[46]:
```
def plot_jaccard(G, df_jaccard):
    df_jaccard = df_jaccard[df_jaccard['source'].isin(G.nodes()) &␣
 ↪df_jaccard['target'].isin(G.nodes())]

    node_color = ['b' for i in range(len(G))]

    max_coeff = df_jaccard['jaccard_coeff'].max()
    for i in range(len(df_jaccard)):
        source = df_jaccard['source'][i]
        target = df_jaccard['target'][i]
        coeff = df_jaccard['jaccard_coeff'][i]
        if coeff == max_coeff:
            node_color[source] = 'r'
            node_color[target] = 'r'

    pos = nx.spring_layout(G, seed = 42)
    nx.draw_networkx_nodes(G, pos, node_color=node_color, cmap = plt.cm.Blues)
    nx.draw_networkx_edges(G, pos)
    nx.draw_networkx_nodes(G, pos, nodelist = [14, 15, 18, 22], node_color =␣
 ↪'r')
    plt.show()

plot_jaccard(G, df_jaccard)
```

```
/usr/local/lib/python3.10/dist-packages/networkx/drawing/nx_pylab.py:433:
UserWarning: No data for colormapping provided via 'c'. Parameters 'cmap' will
be ignored
  node_collection = ax.scatter(
```



vi) Resource allocation index

[58]:
```
def resource_allocation_index(G, source, target):
    common_neighbors = set(G.neighbors(source)) & set(G.neighbors(target))

    ra_index = []
    for neighbor in common_neighbors:
        denominator = len(list(G.neighbors(neighbor)))
        if denominator == 0:
            ra_index.append(0)
        else:
            ra_index.append(sum(1 / len(list(G.neighbors(u))) for u in G.
 ↪neighbors(neighbor)))

    df_ra_index = pd.DataFrame({'source': [source]*len(common_neighbors),
                                'target': [target]*len(common_neighbors),
                                'resource_allocation_index': ra_index})

    df_ra_index.sort_values(by='resource_allocation_index', ascending=False,␣
 ↪inplace=True)
    df_ra_index.reset_index(drop=True, inplace=True)

    return df_ra_index
```

```
print(resource_allocation_index(G, 2, 33))
print(resource_allocation_index(G, 0, 33))
print(resource_allocation_index(G, 1, 33))
print(resource_allocation_index(G, 4, 5))
print(resource_allocation_index(G, 6, 10))
```

```
   source  target  resource_allocation_index
0       2      33                   2.475490
1       2      33                   0.692157
2       2      33                   0.554657
3       2      33                   0.499101
4       2      33                   0.325490
5       2      33                   0.158824
   source  target  resource_allocation_index
0       0      33                   1.204657
1       0      33                   0.554657
2       0      33                   0.499101
3       0      33                   0.399101
   source  target  resource_allocation_index
0       1      33                   0.499101
1       1      33                   0.453268
2       1      33                   0.399101
   source  target  resource_allocation_index
0       4       5                   4.944444
1       4       5                   1.145833
2       4       5                   0.645833
   source  target  resource_allocation_index
0       6      10                   4.944444
1       6      10                   1.145833
2       6      10                   0.645833
```

vii) Adamic-Adar index

[48]:
```
def adamic_adar_index(G, pairs):
    aa_dict = nx.adamic_adar_index(G, pairs)
    df_aa = pd.DataFrame(aa_dict, columns=['source', 'target',␣
 ↪'adamic_adar_index'])
    df_aa = df_aa.sort_values(by='adamic_adar_index', ascending=False)
    return df_aa

pairs = [(2, 33), (0, 33), (1, 33), (4, 5), (6, 10)]
df_aa = adamic_adar_index(G, pairs)
print(df_aa)
```

```
   source  target  adamic_adar_index
0       2      33           4.719381
1       0      33           2.522128
```

```
2       1      33           2.064030
3       4       5           1.992261
4       6      10           1.992261
```

viii) Preferential attachment values

[53]:
```
def preferential_attachment(G, source, target):
    preds = nx.preferential_attachment(G, [(source, target)])
    pa_score = list(preds)[0][2]
    df_pa = pd.DataFrame({'source': [source], 'target': [target],␣
 ↪'preferential_attachment': [pa_score]})
    df_pa = df_pa.sort_values('preferential_attachment', ascending=False)
    return df_pa

df_pa_1 = preferential_attachment(G, 0, 33)
df_pa_2 = preferential_attachment(G, 0, 32)
df_pa_3 = preferential_attachment(G, 2, 33)
df_pa_4 = preferential_attachment(G, 1, 33)
df_pa_5 = preferential_attachment(G, 1, 32)

print(df_pa_1)
print(df_pa_2)
print(df_pa_3)
print(df_pa_4)
print(df_pa_5)
```

```
   source  target  preferential_attachment
0       0      33                      272
   source  target  preferential_attachment
0       0      32                      192
   source  target  preferential_attachment
0       2      33                      170
   source  target  preferential_attachment
0       1      33                      153
   source  target  preferential_attachment
0       1      32                      108
```