Home work3: Random Network

Author: Kunlun Zhu

- Description:
  Network Centrality (due 1.5 weeks after lecture)
  (generate a 100x100 citation matrix)

1. Compute Network centrality measures for co-citation network (degree, eigenvector, in betweenness, etc..).
2. Compute Network centrality measures for bibliographic coupling network (degree, eigenvector, in betweenness, etc..).
3. Compare the two.

Step one:

Initialize the adjacent matrix that would meet the qualification of a DAG, since there is only the possibility that the newly written paper would be able to cite the old one, so the network or graph should apper to be acyclic.
The way I'am going to do it is to give each one of the 100 papers with an index, from 1 to 100 and let's suppose if i < j, then paper with index i had been written before paper with index j.
So the only thing we need to do is to make sure the element of the adjacent matrix A[i][j] = 0 if i <= j

In [1]:
```
#!/usr/bin/python3.9
# -*- coding: utf-8 -*-
#author Kunlun Zhu 2022/7/10
#setup the python environment

import numpy as np
import networkx as nx
import matplotlib.pyplot as plt
```

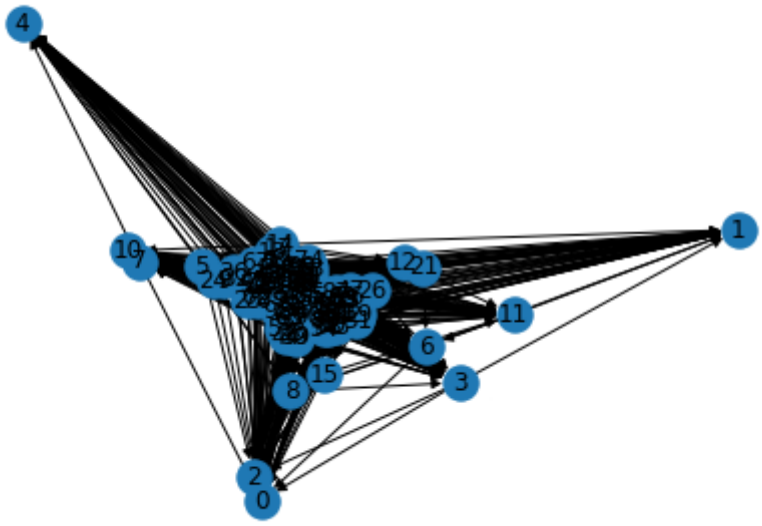
In [2]:
```
Adj_matrix = np.random.randint(2, size=(100,100)) #Adjacency matrix
for j in range(100): # to make sure the Adj_matrix would fit a DAG graph
    for i in range(0, j + 1):
        Adj_matrix[i][j] = 0
print(Adj_matrix)
```

```
[[0 0 0 ... 0 0 0]
 [0 0 0 ... 0 0 0]
 [1 0 0 ... 0 0 0]
 ...
 [0 0 0 ... 0 0 0]
 [1 0 0 ... 1 0 0]
 [0 1 0 ... 1 1 0]]
```

In [3]:
```
link_list = [] # get the link list according to the Adj_matrix
for index, a in np.ndenumerate(Adj_matrix):
    if a == 1:
        link_list.append((index[0], index[1]))
# initialize the graph
G = nx.DiGraph()
```

```
G.add_nodes_from(range(100))
G.add_edges_from(link_list)
nx.draw(G, with_labels=True)
print('Citation Network')
plt.show()
print('If the graph is a DAG:', nx.is_directed_acyclic_graph(G))
```

```
Citation Network
```




```
If the graph is a DAG: True
```

In [4]:

```
A = Adj_matrix
A_t = A.transpose()
Co = np.matmul(A_t, A)
Cocitation_G = nx.DiGraph()
Cocitation_G.add_nodes_from(range(100))
link_list_c = []
for index, c in np.ndenumerate(Co):
    if c >= 1:
        for k in range(c):
            link_list_c.append((index[0], index[1]))
Cocitation_G.add_edges_from(link_list_c)
nx.draw(Cocitation_G, with_labels=True)
print('Cocitation_matrix')
print(Co)
print('Co-citation Network')
plt.show(Cocitation_G)
```

```
Cocitation_matrix
[[46 20 21 ...  1  0  0]
 [20 47 27 ...  1  1  0]
 [21 27 43 ...  0  0  0]
 ...
 [ 1  1  0 ...  2  1  0]
 [ 0  1  0 ...  1  1  0]
 [ 0  0  0 ...  0  0  0]]
Co-citation Network
```

In [5]:

```
A_t = A.transpose()
Bi = np.matmul(A, A_t)
Bibliographic_G = nx.DiGraph()
Bibliographic_G.add_nodes_from(range(100))
link_list_b = []
for index, b in np.ndenumerate(Bi):
    if b >= 1:
        for k in range(b):
            link_list_b.append((index[0], index[1]))
Bibliographic_G.add_edges_from(link_list_b)
nx.draw(Bibliographic_G, with_labels=True)
print('Bibliographic_matrix')
print(Bi)
print('Bibliographic Coupling Network')
plt.show(Bibliographic_G)
```

```
Bibliographic_matrix
[[ 0  0  0 ...  0  0  0]
 [ 0  0  0 ...  0  0  0]
 [ 0  0  1 ...  0  1  0]
 ...
 [ 0  0  0 ... 48 24 22]
 [ 0  0  1 ... 24 48 19]
 [ 0  0  0 ... 22 19 45]]
Bibliographic Coupling Network
```

Task 1:

Compute Network centrality measures for co-citation network (degree, eigenvector, in betweenness, etc..).

In [7]:

```
degree_cen_co = nx.degree_centrality(Cocitation_G)
print('degree centrality of cocitation Network:', degree_cen_co)
between_cen_co = nx.betweenness_centrality(Cocitation_G)
print('Betweenness centrality of cocitation Network:', between_cen_co)
closeness_centrality_co = nx.closeness_centrality(Cocitation_G)
print('Closeness centrality of cocitation Network:', closeness_centrality_co)
eigenvector_centrality_co = nx.eigenvector_centrality(Cocitation_G)
print('Eigenvector centrality of cocitation Network:', eigenvector_centrality_co)
try:
    katz_centrality_co = nx.katz_centrality(Cocitation_G)
    print('Katz centrality of cocitation Network:', katz_centrality_co)
except:
    print('Katz centrality doesn\'t exist for this particular cocitation network')
pr_co = nx.pagerank(G, alpha=0.85)
print('Page rank of cociatation Network:', pr_co)
```

```
degree centrality of cocitation Network: {0: 1.9595959595959598, 1: 1.959595959595959
8, 2: 1.9191919191919193, 3: 1.9595959595959598, 4: 2.0, 5: 1.878787878787879, 6: 1.93
93939393939394, 7: 1.8585858585858588, 8: 2.0, 9: 1.9393939393939394, 10: 1.9595959595
959598, 11: 1.9393939393939394, 12: 1.9191919191919193, 13: 1.9393939393939394, 14: 1.
9595959595959598, 15: 1.97979797979798, 16: 1.8989898989898992, 17: 1.959595959595959
8, 18: 2.0, 19: 1.9191919191919193, 20: 1.9191919191919193, 21: 1.9393939393939394, 2
2: 1.97979797979798, 23: 1.9393939393939394, 24: 1.97979797979798, 25: 1.9393939393939
394, 26: 1.9595959595959598, 27: 1.9393939393939394, 28: 1.9393939393939394, 29: 1.939
3939393939394, 30: 1.97979797979798, 31: 1.97979797979798, 32: 2.0, 33: 1.959595959595
9598, 34: 1.97979797979798, 35: 2.0, 36: 2.0, 37: 1.97979797979798, 38: 1.919191919191
9193, 39: 1.9595959595959598, 40: 2.0, 41: 1.97979797979798, 42: 1.97979797979798, 43:
1.7979797979797982, 44: 1.9595959595959598, 45: 1.97979797979798, 46: 1.91919191919191
93, 47: 1.97979797979798, 48: 1.97979797979798, 49: 1.9595959595959598, 50: 1.95959595
95959598, 51: 1.9393939393939394, 52: 1.97979797979798, 53: 1.9595959595959598, 54: 1.
878787878787879, 55: 1.9393939393939394, 56: 2.0, 57: 1.9393939393939394, 58: 1.979797
97979798, 59: 1.9595959595959598, 60: 2.0, 61: 1.8585858585858588, 62: 1.8787878787878
79, 63: 1.9393939393939394, 64: 2.0, 65: 1.9393939393939394, 66: 1.97979797979798, 67:
1.9595959595959598, 68: 1.8989898989898992, 69: 1.9595959595959598, 70: 2.0, 71: 1.939
3939393939394, 72: 1.8989898989898992, 73: 2.0, 74: 1.9393939393939394, 75: 2.0, 76:
1.9393939393939394, 77: 2.0, 78: 2.0, 79: 1.97979797979798, 80: 1.8989898989898992, 8
1: 1.9191919191919193, 82: 1.9393939393939394, 83: 1.8989898989898992, 84: 2.0, 85: 1.
8989898989898992, 86: 1.9595959595959598, 87: 1.878787878787879, 88: 2.0, 89: 1.898989
8989898992, 90: 1.8585858585858588, 91: 1.575757575757576, 92: 1.6565656565656568, 93:
1.5353535353535355, 94: 1.777777777777778, 95: 1.5353535353535355, 96: 0.9696969696969
697, 97: 1.494949494949495, 98: 0.9090909090909092, 99: 0.0}
Betweenness centrality of cocitation Network: {0: 0.0003332522833170926, 1: 0.00054298
44118822193, 2: 0.0002217621664181527, 3: 0.0004848767604638036, 4: 0.0008301461699934
861, 5: 0.0001375624880595965, 6: 0.0004726618099742557, 7: 6.43197461808907e-05, 8:
0.0008301461699934861, 9: 0.000262186685464067, 10: 0.0005328442663346773, 11: 0.00030
580131447501615, 12: 0.00026199740094900477, 13: 0.0005026584936362471, 14: 0.00048487
67604638036, 15: 0.000561668554519216, 16: 0.00018146698289908702, 17: 0.0003332522833
170926, 18: 0.0008301461699934861, 19: 0.0002217621664181527, 20: 0.00026199740094900
477, 21: 0.0004658465525442283, 22: 0.0005923597595510934, 23: 0.000262186685464067, 2
4: 0.000561668554519216, 25: 0.000415570508422617, 26: 0.0003332522833170926, 27: 0.00
0262186685464067, 28: 0.0004774307916942591, 29: 0.0004261832092860075, 30: 0.00056166
8554519216, 31: 0.000765205859322177, 32: 0.0008301461699934861, 33: 0.000333252283317
0926, 34: 0.0005923597595510934, 35: 0.0008301461699934861, 36: 0.0008301461699934861,
37: 0.0005923597595510934, 38: 0.0002055963850638418, 39: 0.0005429844118822193, 40:
0.0008301461699934861, 41: 0.000561668554519216, 42: 0.000561668554519216, 43: 1.14026
17838450599e-05, 44: 0.0005220371576431298, 45: 0.000765205859322177, 46: 0.0003603126
```

7496625276, 47: 0.0005923597595510934, 48: 0.0005923597595510934, 49: 0.00049236230247
80293, 50: 0.0005444118666678892, 51: 0.0004866403504086634 5, 52: 0.00076520585932217
7, 53: 0.0004923623024780293, 54: 0.0001685861765245804 6, 55: 0.000262186685464067, 5
6: 0.0008301461699934861, 57: 0.000262186685464067, 58: 0.000765205859322177, 59: 0.00
05220371576431298, 60: 0.0008301461699934861, 61: 8.68502218001174e-05, 62: 0.00017057
687863252378, 63: 0.0005026584936362471, 64: 0.0008301461699934861, 65: 0.000415570508
422617, 66: 0.000561668554519216, 67: 0.0005444118666678892, 68: 0.0001650134569016729
2, 69: 0.0004923623024780293, 70: 0.0008301461699934861, 71: 0.000415570508422617, 72:
0.0001382788429069238 7, 73: 0.0008301461699934861, 74: 0.000262186685464067, 75: 0.000
8301461699934861, 76: 0.0004658465525442283, 77: 0.0008301461699934861, 78: 0.00083014
61699934861, 79: 0.0005923597595510934, 80: 0.0004364705343968549, 81: 0.0004464678885
3734573, 82: 0.0004261832092860075, 83: 0.0001781454162217653, 84: 0.0008301461699934 8
61, 85: 0.0003914826170716552 4, 86: 0.0004923623024780293, 87: 0.0004457816867342866,
88: 0.0008301461699934861, 89: 0.0002759283572221856 3, 90: 0.0004695137265047747 6, 91:
8.444732045634198e-05, 92: 0.0002250784061615319 5, 93: 0.0002449334867485973 4, 94: 0.0
006237680667167541, 95: 0.0001894117357143698 3, 96: 0.0, 97: 0.0002401307603708894, 9
8: 0.0, 99: 0.0}
Closeness centrality of cocitation Network: {0: 0.9701010101010101, 1: 0.9701010101010
101, 2: 0.951079421667657, 3: 0.9701010101010101, 4: 0.98989898989899, 5: 0.9327894327
894328, 6: 0.9604960496049605, 7: 0.923905723905724, 8: 0.98989898989899, 9: 0.9604960
496049605, 10: 0.9701010101010101, 11: 0.9604960496049605, 12: 0.951079421667657, 13:
0.9604960496049605, 14: 0.9701010101010101, 15: 0.9799000102030406, 16: 0.941845640874
7672, 17: 0.9701010101010101, 18: 0.98989898989899, 19: 0.951079421667657, 20: 0.95107
9421667657, 21: 0.9604960496049605, 22: 0.9799000102030406, 23: 0.9604960496049605, 2
4: 0.9799000102030406, 25: 0.9604960496049605, 26: 0.9701010101010101, 27: 0.960496049
6049605, 28: 0.9604960496049605, 29: 0.9604960496049605, 30: 0.9799000102030406, 31:
0.9799000102030406, 32: 0.98989898989899, 33: 0.9701010101010101, 34: 0.97990001020304
06, 35: 0.98989898989899, 36: 0.98989898989899, 37: 0.9799000102030406, 38: 0.95107942
1667657, 39: 0.9701010101010101, 40: 0.98989898989899, 41: 0.9799000102030406, 42: 0.9
799000102030406, 43: 0.8982416760194538, 44: 0.9701010101010101, 45: 0.979900010203040
6, 46: 0.951079421667657, 47: 0.9799000102030406, 48: 0.9799000102030406, 49: 0.970101
0101010101, 50: 0.9701010101010101, 51: 0.9604960496049605, 52: 0.9799000102030406, 5
3: 0.9701010101010101, 54: 0.9327894327894328, 55: 0.9604960496049605, 56: 0.989898989
89899, 57: 0.9604960496049605, 58: 0.9799000102030406, 59: 0.9701010101010101, 60: 0.9
8989898989899, 61: 0.923905723905724, 62: 0.9327894327894328, 63: 0.9604960496049605,
64: 0.98989898989899, 65: 0.9604960496049605, 66: 0.9799000102030406, 67: 0.9701010101
010101, 68: 0.9418456408747672, 69: 0.9701010101010101, 70: 0.98989898989899, 71: 0.96
04960496049605, 72: 0.9418456408747672, 73: 0.98989898989899, 74: 0.9604960496049605,
75: 0.98989898989899, 76: 0.9604960496049605, 77: 0.98989898989899, 78: 0.989898989898
99, 79: 0.9799000102030406, 80: 0.9418456408747672, 81: 0.951079421667657, 82: 0.96049
60496049605, 83: 0.9418456408747672, 84: 0.98989898989899, 85: 0.9418456408747672, 86:
0.9701010101010101, 87: 0.9327894327894328, 88: 0.98989898989899, 89: 0.941845640874 76
72, 90: 0.923905723905724, 91: 0.8152109328579917, 92: 0.8435660957400087, 93: 0.80173
63719843059, 94: 0.8900009266981745, 95: 0.8017363719843059, 96: 0.6510745034234968, 9
7: 0.7887000082122034, 98: 0.6382243487506646, 99: 0.0}
Eigenvector centrality of cocitation Network: {0: 0.103098596350226, 1: 0.102680630939
44653, 2: 0.10135682630613675, 3: 0.10280969940011878, 4: 0.10413350403342853, 5: 0.09
951156946410566, 6: 0.10183137208452099, 7: 0.09872856874963414, 8: 0.1041335040334285
3, 9: 0.10227454519495145, 10: 0.10272168138024954, 11: 0.10212579695326539, 12: 0.101
20807806445067, 13: 0.10172638793924248, 14: 0.10280969940011878, 15: 0.10363375055539
331, 16: 0.10042507734997914, 17: 0.103098596350226, 18: 0.10413350403342853, 19: 0.10
135682630613675, 20: 0.10120807806445067, 21: 0.10187242252532402, 22: 0.1035983498282
6123, 23: 0.10227454519495145, 24: 0.10363375055539331, 25: 0.10196244965469929, 26:
0.103098596350226, 27: 0.10227454519495145, 28: 0.10173822426222932, 29: 0.10193303095
210707, 30: 0.10363375055539331, 31: 0.10325683558541683, 32: 0.10413350403342853, 33:
0.103098596350226, 34: 0.10359834982826123, 35: 0.10413350403342853, 36: 0.10413350403
342853, 37: 0.10359834982826123, 38: 0.101402087749881, 39: 0.10268063093944653, 40:
0.10413350403342853, 41: 0.10363375055539331, 42: 0.10363375055539331, 43: 0.095736825
04776347, 44: 0.10274909097333357, 45: 0.10325683558541683, 46: 0.10108578120668758, 4
7: 0.10359834982826123, 48: 0.10359834982826123, 49: 0.10278650080997383, 50: 0.102597
54974200253, 51: 0.10180396249143484, 52: 0.10325683558541683, 53: 0.1027865008099738
3, 54: 0.09939308753952959, 55: 0.10227454519495145, 56: 0.10413350403342853, 57: 0.10
227454519495145, 58: 0.10325683558541683, 59: 0.10274909097333357, 60: 0.10413350403342
853, 61: 0.09863761467169851, 62: 0.09938010697554461, 63: 0.10172638793924248, 64: 0.

```
10413350403342853, 65: 0.10196244965469929, 66: 0.10363375055539331, 67: 0.10259754974
200253, 68: 0.10048436886106629, 69: 0.10278650080997383, 70: 0.10413350403342853, 71:
0.10196244965469929, 72: 0.10057803659460646, 73: 0.10413350403342853, 74: 0.102274545
19495145, 75: 0.10413350403342853, 76: 0.10187242252532402, 77: 0.10413350403342853, 7
8: 0.10413350403342853, 79: 0.10359834982826123, 80: 0.09978088012090537, 81: 0.100849
7194912308, 82: 0.10193303095210707, 83: 0.10042928835292037, 84: 0.10413350403342853,
85: 0.09986706472051289, 86: 0.10278650080997383, 87: 0.09863143671388618, 88: 0.10413
350403342853, 89: 0.10007082868210226, 90: 0.09734648878927762, 91: 0.0834463953738916
6, 92: 0.08735339178363868, 93: 0.08064528656031712, 94: 0.09259589680373558, 95: 0.08
083670116230784, 96: 0.05093813754566303, 97: 0.0784372016141213, 98: 0.04756826603350
201, 99: 1.2254254330815014e-11}
Katz centrality doesn't exist for this particular cocitation network
Page rank of cociatation Network: {0: 0.09058605856348535, 1: 0.045068598642720635, 2:
0.04683053575631101, 3: 0.04561674745073572, 4: 0.04308332640722102, 5: 0.047938457632
17866, 6: 0.03188569562354269, 7: 0.02816312456562796, 8: 0.020707906021682036, 9: 0.0
2456526221177652, 10: 0.01583648162457194, 11: 0.02016678636177043, 12: 0.016528913335
166595, 13: 0.015233258531395366, 14: 0.010299493688609548, 15: 0.016778946567338252,
16: 0.012608822507458864, 17: 0.014299684965243621, 18: 0.011472324509901993, 19: 0.01
1764881354764011, 20: 0.010398792814403743, 21: 0.0123546817238984, 22: 0.011905181209
110108, 23: 0.008816871854762305, 24: 0.010250304032934577, 25: 0.009972640294767842,
26: 0.00890385613624481, 27: 0.007486295311680811, 28: 0.008115362405202593, 29: 0.009
430092319544168, 30: 0.0076896223880021115, 31: 0.008137070542894366, 32: 0.0083536182
40105751, 33: 0.0072908946167526256, 34: 0.007305721451162465, 35: 0.00735166362165814
8, 36: 0.006374736143351093, 37: 0.007104905889201699, 38: 0.00676451382644947, 39: 0.
006369481590551973, 40: 0.006683265996661983, 41: 0.006618197323474424, 42: 0.00638798
55723416494, 43: 0.006858537911368485, 44: 0.0059264077676199935, 45: 0.00613630400447
9624, 46: 0.005269946828578273, 47: 0.006303003237185079, 48: 0.005888559410744286, 4
9: 0.0056516966769973925, 50: 0.004953261131034949, 51: 0.005074272694453728, 52: 0.00
5580191966789377, 53: 0.004898818060669698, 54: 0.005950304596227535, 55: 0.0047092288
57285012, 56: 0.004872725842855534, 57: 0.00493937083070439, 58: 0.00499169856688612,
59: 0.005068708651570546, 60: 0.00492090790482838, 61: 0.004298512738094142, 62: 0.004
560203785702542, 63: 0.00451083255249942, 64: 0.004443388995398431, 65: 0.004532382321
575465, 66: 0.0039899114148262485, 67: 0.0038976422235819435, 68: 0.00391013290740434,
69: 0.004330091316847308, 70: 0.004163869713212401, 71: 0.003664137258350037, 72: 0.00
380197103930773 28, 73: 0.003727748140703136, 74: 0.0038805237263952602, 75: 0.00400873
5242982695, 76: 0.00384687621115237, 77: 0.003881631049075333, 78: 0.00382963267864389
58, 79: 0.0036205144168116703, 80: 0.003457914054564237, 81: 0.0034421730969147026, 8
2: 0.0035545989616267756, 83: 0.003445788370368586, 84: 0.003564041307935129, 85: 0.00
33048620692907966, 86: 0.003413451926201289, 87: 0.0033258767690037007, 88: 0.00341668
73096442988, 89: 0.003382044247322296, 90: 0.0032503928974639777, 91: 0.00312107123600
14692, 92: 0.0031904670078347188, 93: 0.003129482595772507, 94: 0.0031790649012184685,
95: 0.003127893285853052, 96: 0.0030745579798167836, 97: 0.003130621893785622, 98: 0.0
03076147289736239, 99: 0.0030191185001433203}
```

Task 2:

Compute Network centrality measures for bibliographic coupling network (degree, eigenvector, in betweenness, etc..).

In [8]:

```
degree_cen_bib = nx.degree_centrality(Bibliographic_G)
print('degree centrality of bibliographic coupling Network:', degree_cen_bib)
between_cen_bib = nx.betweenness_centrality(Bibliographic_G)
print('Betweenness centrality of bibliographic coupling Network:', between_cen_bib)
closeness_centrality_bib = nx.closeness_centrality(Bibliographic_G)
print('Closeness centrality of bibliographic coupling Network:', closeness_centrality_
eigenvector_centrality_bib = nx.eigenvector_centrality(Bibliographic_G)
print('Eigenvector centrality of bibliographic coupling Network:', eigenvector_central
try:
    katz_centrality_bib = nx.katz_centrality(Bibliographic_G)
    print('Katz centrality of bibliographic coupling Network:', katz_centrality_bib)
except:
    print('Katz centrality doesn\'t exist for this particular bibliographic coupling n
```

```
pr_bib = nx.pagerank(Bibliographic_G, alpha=0.85)
print('Page rank of bibliographic coupling Network:', pr_bib)
```

```
degree centrality of bibliographic coupling Network: {0: 0.0, 1: 0.0, 2: 0.92929292929
29294, 3: 1.595959595959596, 4: 0.0, 5: 1.595959595959596, 6: 1.878787878787879, 7: 1.
696969696969697, 8: 1.8989898989898992, 9: 1.9191919191919193, 10: 1.4141414141414144,
11: 1.676767676767677, 12: 1.8989898989898992, 13: 1.9191919191919193, 14: 1.919191919
1919193, 15: 1.7979797979797982, 16: 1.9595959595959598, 17: 1.9191919191919193, 18:
1.9191919191919193, 19: 1.8989898989898992, 20: 1.9393939393939394, 21: 1.818181818181
8183, 22: 1.8383838383838385, 23: 1.9595959595959598, 24: 1.9595959595959598, 25: 1.89
89898989898992, 26: 1.9393939393939394, 27: 1.9393939393939394, 28: 1.959595959595959
8, 29: 1.8989898989898992, 30: 1.9595959595959598, 31: 1.9393939393939394, 32: 1.95959
59595959598, 33: 1.9595959595959598, 34: 1.9595959595959598, 35: 1.9595959595959598, 3
6: 1.9595959595959598, 37: 1.9393939393939394, 38: 1.9595959595959598, 39: 1.939393939
3939394, 40: 1.9191919191919193, 41: 1.878787878787879, 42: 1.9191919191919193, 43: 1.
9595959595959598, 44: 1.9393939393939394, 45: 1.9393939393939394, 46: 1.93939393939393
94, 47: 1.9191919191919193, 48: 1.9191919191919193, 49: 1.9393939393939394, 50: 1.9191
919191919193, 51: 1.9393939393939394, 52: 1.878787878787879, 53: 1.9595959595959598, 5
4: 1.9595959595959598, 55: 1.9393939393939394, 56: 1.9393939393939394, 57: 1.959595959
5959598, 58: 1.8989898989898992, 59: 1.9191919191919193, 60: 1.8585858585858588, 61:
1.9393939393939394, 62: 1.9595959595959598, 63: 1.9393939393939394, 64: 1.838383838383
8385, 65: 1.8989898989898992, 66: 1.8989898989898992, 67: 1.8585858585858588, 68: 1.91
919191919191919193, 69: 1.9393939393939394, 70: 1.9595959595959598, 71: 1.919191919191919
3, 72: 1.9393939393939394, 73: 1.8989898989898992, 74: 1.8989898989898992, 75: 1.85858
58585858588, 76: 1.9191919191919193, 77: 1.9595959595959598, 78: 1.8989898989898992, 7
9: 1.9393939393939394, 80: 1.9595959595959598, 81: 1.9191919191919193, 82: 1.939393939
3939394, 83: 1.9191919191919193, 84: 1.8989898989898992, 85: 1.9191919191919193, 86:
1.9393939393939394, 87: 1.8383838383838385, 88: 1.9393939393939394, 89: 1.939393939393
9394, 90: 1.9393939393939394, 91: 1.9595959595959598, 92: 1.9595959595959598, 93: 1.91
919191919191919193, 94: 1.9191919191919193, 95: 1.9393939393939394, 96: 1.939393939393939
4, 97: 1.8585858585858588, 98: 1.9595959595959598, 99: 1.8989898989898992}
Betweenness centrality of bibliographic coupling Network: {0: 0.0, 1: 0.0, 2: 0.0, 3:
0.00024642926456710574, 4: 0.0, 5: 7.872830256908321e-05, 6: 0.00046205247466466794,
7: 0.000328459359289791, 8: 0.000476833291116191, 9: 0.0004890287309704329, 10: 3.9004
271245100506e-05, 11: 6.818083238440237e-05, 12: 0.00022078662263883112, 13: 0.0002282
556423443244, 14: 0.00019829855884132287, 15: 0.00032294879557956326, 16: 0.0005198233
454028241, 17: 0.0002282556423443244, 18: 0.00019829855884132287, 19: 0.00024225927286
78017, 20: 0.00027824595611452906, 21: 0.00015315316260858377, 22: 0.00013588651142456
307, 23: 0.0005198233454028241, 24: 0.0005198233454028241, 25: 0.0001812920896725305,
26: 0.00027824595611452906, 27: 0.00043381291685650256, 28: 0.0005198233454028241, 29:
0.00015192479004104667, 30: 0.0005198233454028241, 31: 0.00027824595611452906, 32: 0.0
005198233454028241, 33: 0.0005198233454028241, 34: 0.0005198233454028241, 35: 0.000519
8233454028241, 36: 0.0005198233454028241, 37: 0.00027824595611452906, 38: 0.0005198233
454028241, 39: 0.0004796448764980785, 40: 0.00039695933606927175, 41: 0.00015994694509
095754, 42: 0.00038518018958320324, 43: 0.0005198233454028241, 44: 0.00047964487649807
85, 45: 0.0005102677525069516, 46: 0.00027824595611452906, 47: 0.0002312824034427352,
48: 0.00045968047741340017, 49: 0.00027824595611452906, 50: 0.00019829855884132287, 5
1: 0.0004675740731595961, 52: 0.00012049602670870871, 53: 0.0005198233454028241, 54:
0.0005198233454028241, 55: 0.00027824595611452906, 56: 0.00027824595611452906, 57: 0.0
005198233454028241, 58: 0.00019350199089447157, 59: 0.00024447586494614495, 60: 0.0001
0570787382583719, 61: 0.00043381291685650256, 62: 0.0005198233454028241, 63: 0.0002782
4595611452906, 64: 7.71825339200615e-05, 65: 0.00023513085634751642, 66: 0.00018129208
96725305, 67: 0.00019154601426606875, 68: 0.00024447586494614495, 69: 0.00046757407315
95961, 70: 0.0005198233454028241, 71: 0.0002434923046646763, 72: 0.0002782459561145290
6, 73: 0.00020781508025674583, 74: 0.00019137450144927443, 75: 0.00013817698990551772,
76: 0.00024447586494614495, 77: 0.0005198233454028241, 78: 0.0001812920896725305, 79:
0.00043381291685650256, 80: 0.0005198233454028241, 81: 0.0002282556423443244, 82: 0.00
027824595611452906, 83: 0.0002653335626996276, 84: 0.00020781508025674583, 85: 0.00019
829855884132287, 86: 0.0004675740731595961, 87: 0.00019067587999704368, 88: 0.00027824
595611452906, 89: 0.00027824595611452906, 90: 0.00043381291685650256, 91: 0.0005198233
454028241, 92: 0.0005198233454028241, 93: 0.0004304271198914084, 94: 0.000385180189583
20324, 95: 0.00043381291685650256, 96: 0.00043381291685650256, 97: 0.00012968799857529
688, 98: 0.0005198233454028241, 99: 0.00018102942849660466}
Closeness centrality of bibliographic coupling Network: {0: 0.0, 1: 0.0, 2: 0.63327149
```

04143475, 3: 0.8165869218500797, 4: 0.0, 5: 0.8165869218500797, 6: 0.9309090909090909, 7: 0.8540450375312761, 8: 0.9403122130394859, 9: 0.9499072356215214, 10: 0.7568366592756837, 11: 0.8462809917355372, 12: 0.9403122130394859, 13: 0.9499072356215214, 14: 0.9499072356215214, 15: 0.8951048951048952, 16: 0.9696969696969697, 17: 0.9499072356215214, 18: 0.9499072356215214, 19: 0.9403122130394859, 20: 0.9597000937207123, 21: 0.9037952338923213, 22: 0.912655971479501, 23: 0.9696969696969697, 24: 0.9696969696969697, 25: 0.9403122130394859, 26: 0.9597000937207123, 27: 0.9597000937207123, 28: 0.9696969696969697, 29: 0.9403122130394859, 30: 0.9696969696969697, 31: 0.9597000937207123, 32: 0.9696969696969697, 33: 0.9696969696969697, 34: 0.9696969696969697, 35: 0.9696969696969697, 36: 0.9696969696969697, 37: 0.9597000937207123, 38: 0.9696969696969697, 39: 0.9597000937207123, 40: 0.9499072356215214, 41: 0.9309090909090909, 42: 0.9499072356215214, 43: 0.9696969696969697, 44: 0.9597000937207123, 45: 0.9597000937207123, 46: 0.9597000937207123, 47: 0.9499072356215214, 48: 0.9499072356215214, 49: 0.9597000937207123, 50: 0.9499072356215214, 51: 0.9597000937207123, 52: 0.9309090909090909, 53: 0.9696969696969697, 54: 0.9696969696969697, 55: 0.9597000937207123, 56: 0.9597000937207123, 57: 0.9696969696969697, 58: 0.9403122130394859, 59: 0.9499072356215214, 60: 0.9216921692169217, 61: 0.9597000937207123, 62: 0.9696969696969697, 63: 0.9597000937207123, 64: 0.912655971479501, 65: 0.9403122130394859, 66: 0.9403122130394859, 67: 0.9216921692169217, 68: 0.9499072356215214, 69: 0.9597000937207123, 70: 0.9696969696969697, 71: 0.9499072356215214, 72: 0.9597000937207123, 73: 0.9403122130394859, 74: 0.9403122130394859, 75: 0.9216921692169217, 76: 0.9499072356215214, 77: 0.9696969696969697, 78: 0.9403122130394859, 79: 0.9597000937207123, 80: 0.9696969696969697, 81: 0.9499072356215214, 82: 0.9597000937207123, 83: 0.9499072356215214, 84: 0.9403122130394859, 85: 0.9499072356215214, 86: 0.9597000937207123, 87: 0.912655971479501, 88: 0.9597000937207123, 89: 0.9597000937207123, 90: 0.9597000937207123, 91: 0.9696969696969697, 92: 0.9696969696969697, 93: 0.9499072356215214, 94: 0.9499072356215214, 95: 0.9597000937207123, 96: 0.9597000937207123, 97: 0.9216921692169217, 98: 0.9696969696969697, 99: 0.9403122130394859}
Eigenvector centrality of bibliographic coupling Network: {0: 1.2978124159626023e-11, 1: 1.2978124159626023e-11, 2: 0.04955963963672768, 3: 0.08520135678967793, 4: 1.2978124159626023e-11, 5: 0.08580883181578576, 6: 0.10001538081162063, 7: 0.09049687018527068, 8: 0.1010728219118855, 9: 0.10214068758655662, 10: 0.07611655001198496, 11: 0.09029120490431004, 12: 0.1017639340568182, 13: 0.10283054621341113, 14: 0.1029269383494632, 15: 0.09609944272799295, 16: 0.10426035062952996, 17: 0.10283054621341113, 18: 0.1029269383494632, 19: 0.10167962402225568, 20: 0.1037345224230821, 21: 0.09764694989213704, 22: 0.09880933998207803, 23: 0.10426035062952996, 24: 0.10426035062952996, 25: 0.10192012874009163, 26: 0.1037345224230821, 27: 0.10345276655591105, 28: 0.1042603506295299, 29: 0.10202296213979221, 30: 0.10426035062952996, 31: 0.1037345224230821, 32: 0.10426035062952996, 33: 0.10426035062952996, 34: 0.10426035062952996, 35: 0.10426035062952996, 36: 0.10426035062952996, 37: 0.1037345224230821, 38: 0.10426035062952996, 39: 0.10330237844112415, 40: 0.10249479436750523, 41: 0.10088308290470296, 42: 0.10254234908259155, 43: 0.10426035062952996, 44: 0.10330237844112415, 45: 0.10318154917214198, 46: 0.1037345224230821, 47: 0.10282410494976259, 48: 0.10226636258860315, 49: 0.1037345224230821, 50: 0.1029269383494632, 51: 0.10334993315621047, 52: 0.10106498995138642, 53: 0.10426035062952996, 54: 0.10426035062952996, 55: 0.1037345224230821, 56: 0.1037345224230821, 57: 0.10426035062952996, 58: 0.10187257402500532, 59: 0.10277436277184919, 60: 0.10002678663603831, 61: 0.10345276655591105, 62: 0.10426035062952996, 63: 0.1037345224230821, 64: 0.0990688144476325, 65: 0.10171321550866803, 66: 0.10192012874009163, 67: 0.09967743248309134, 68: 0.10277436277184919, 69: 0.10334993315621047, 70: 0.10426035062952996, 71: 0.1027765502346763, 72: 0.1037345224230821, 73: 0.10181094589697093, 74: 0.10185457219876475, 75: 0.09989882182567757, 76: 0.10277436277184919, 77: 0.10426035062952996, 78: 0.10192012874009163, 79: 0.10345276655591105, 80: 0.10426035062952996, 81: 0.10283054621341113, 82: 0.1037345224230821, 83: 0.10268617488676587, 84: 0.10181094589697093, 85: 0.1029269383494632, 86: 0.10334993315621047, 87: 0.098900299280685, 88: 0.1037345224230821, 89: 0.1037345224230821, 90: 0.10345276655591105, 91: 0.10426035062952996, 92: 0.10426035062952996, 93: 0.10239196096780465, 94: 0.10254234908259155, 95: 0.10345276655591105, 96: 0.10345276655591105, 97: 0.09992366487539701, 98: 0.10426035062952996, 99: 0.101907338033023}
Katz centrality doesn't exist for this particular bibliographic coupling network
Page rank of bibliographic coupling Network: {0: 0.0015392544753131253, 1: 0.0015392544753131253, 2: 0.005824106031805391, 3: 0.008889511016571964, 4: 0.0015392544753131253, 5: 0.008873448594756216, 6: 0.010194839525220234, 7: 0.009356171131426746, 8: 0.010288801562040561, 9: 0.010381046548419195, 10: 0.008037354407358956, 11: 0.009242346176411701, 12: 0.010271074655763114, 13: 0.01036402066358503, 14: 0.01036207793917681, 15: 0.009816729957245253, 16: 0.010567309354558439, 17: 0.01036402066358503, 18: 0.010362

7793917681, 19: 0.010272247637272507, 20: 0.010459672559069745, 21: 0.0098965315151969
68, 22: 0.009987935440426771, 23: 0.010567309354558439, 24: 0.010567309354558439, 25:
0.010268548059293949, 26: 0.010459672559069745, 27: 0.010469714734665502, 28: 0.010567
309354558439, 29: 0.010266426043692094, 30: 0.010567309354558439, 31: 0.01045967255906
9745, 32: 0.010567309354558439, 33: 0.010567309354558439, 34: 0.010567309354558439, 3
5: 0.010567309354558439, 36: 0.010567309354558439, 37: 0.010459672559069745, 38: 0.010
567309354558439, 39: 0.010472662323644345, 40: 0.010375067703751408, 41: 0.01017451205
0840927, 42: 0.010374242130374422, 43: 0.010567309354558439, 44: 0.010472662323644345,
45: 0.010474424116518222, 46: 0.010459672559069745, 47: 0.010364199954778663, 48: 0.01
0379197619108028, 49: 0.010459672559069745, 50: 0.01036207793917681, 51: 0.01047183675
0267357, 52: 0.010171779012778001, 53: 0.010567309354558439, 54: 0.010567309354558439,
55: 0.010459672559069745, 56: 0.010459672559069745, 57: 0.010567309354558439, 58: 0.01
0269373632670937, 59: 0.0103649922167096, 60: 0.010078280996795632, 61: 0.010469714734
665502, 62: 0.010567309354558439, 63: 0.010459672559069745, 64: 0.00998363396588154, 6
5: 0.010271810535800523, 66: 0.010268548059293949, 67: 0.010084048250966763, 68: 0.010
3649922167096, 69: 0.010471836750267357, 70: 0.010567309354558439, 71: 0.0103650255281
55653, 72: 0.010459672559069745, 73: 0.010270262604131159, 74: 0.010269045266921491, 7
5: 0.010080686036024727, 76: 0.0103649922167096, 77: 0.010567309354558439, 78: 0.01026
8548059293949, 79: 0.010469714734665502, 80: 0.010567309354558439, 81: 0.0103640206635
8503, 82: 0.010459672559069745, 83: 0.010366382024432153, 84: 0.010270262604131159, 8
5: 0.01036207793917681, 86: 0.010471836750267357, 87: 0.009986006774294526, 88: 0.0104
59672559069745, 89: 0.010459672559069745, 90: 0.010469714734665502, 91: 0.010567309354
558439, 92: 0.010567309354558439, 93: 0.010377189719353263, 94: 0.010374242130374422,
95: 0.010469714734665502, 96: 0.010469714734665502, 97: 0.010079792784531886, 98: 0.01
0567309354558439, 99: 0.010268319879722937}

Task 3: Compare the two.

For degree centrality we can see both network are quiet similar: All the degree centrality of each node are similar, around 1.9

For other centrality we also don't see a very obvious diffence bettwen the two.

By the difference between the two network in HW1 we notice that.

The co-citation value more defined by the in-degree number, and the bibliographic coupling Network is more affected by the out-degree number.

That is to say, the very impactful and original paper would more likely to achieve high centrality in co-citation netwrok, and a survey or review paper tend to have higher centrality in bibliographic netwrok.