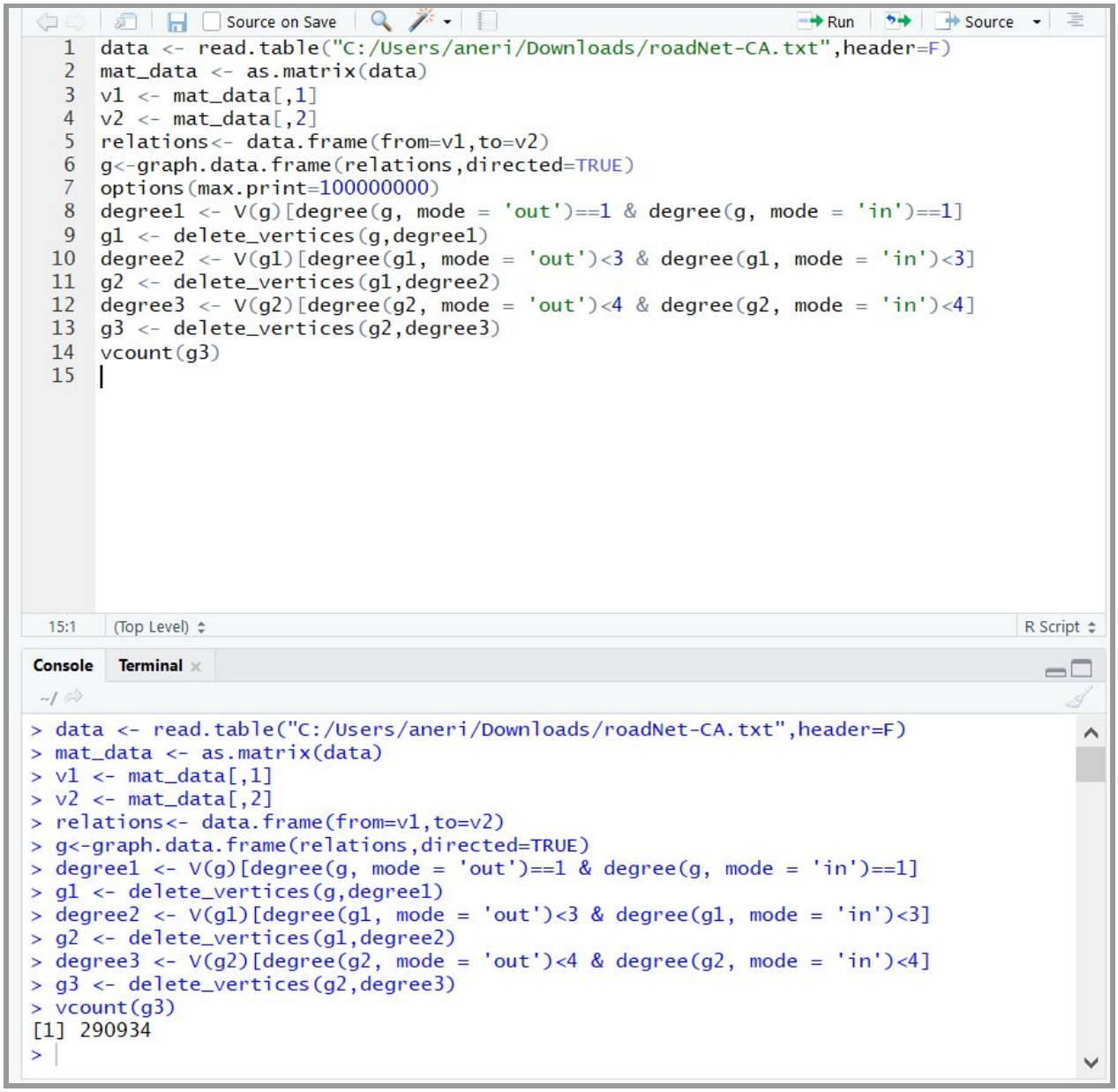
Class project #1
R and Graph Analytics

Creating and reducing the graph:

data <- read.table("C:/Users/aneri/Downloads/roadNet-CA.txt",header=F) **#reads the files from the destination**
mat_data <- as.matrix(data) **#mat_data stores the data as matrix converts to matrix**
v1 <- mat_data[,1] **#separate vertices 1**
v2 <- mat_data[,2] **#separate vertices 2**
relations<- data.frame(from=v1,to=v2) **#relations has the dataframe from vertices 1 to 2**
g<-graph.data.frame(relations,directed=TRUE) **#converts the data frame into the graph**
options(max.print=100000000) **#for printing maximum**
degree1 <- V(g)[degree(g, mode = 'out')==1 & degree(g, mode = 'in')==1] **#stores the in and out degrees which are 1**
g1 <- delete_vertices(g,degree1) **#deletes the degree 1 vertices**
degree2 <- V(g1)[degree(g1, mode = 'out')<3 & degree(g1, mode = 'in')<3] **#stores the in and out degrees which are less than 3**
g2 <- delete_vertices(g1,degree2) **#deletes the vertices less than 3**
degree3 <- V(g2)[degree(g2, mode = 'out')<4 & degree(g2, mode = 'in')<4] **#stores the in and out degrees which are less than 4**
g3 <- delete_vertices(g2,degree3) **#deletes the vertices less than 4**
vcount(g3) **#counts the number of vertices**

Table after deleting vertices:

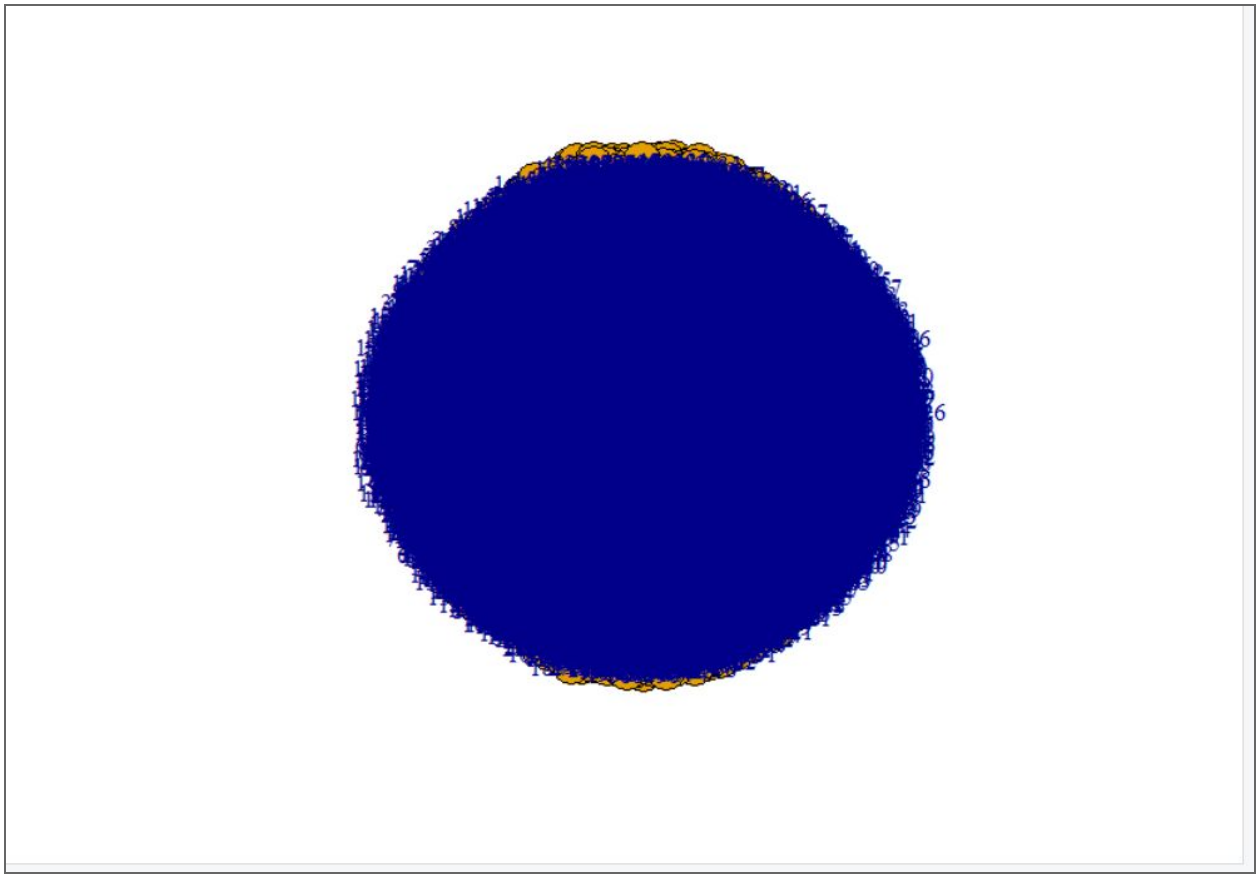
Function	Before Deleting	Remaining Vertices
Degree 1 vertices deleted	1965206	1644179
Vertices less than degree 3 deleted	1644179	1231291
Vertices less than degree 4 deleted	1231291	290934



```
data <- read.table("C:/Users/aneri/Downloads/roadNet-CA.txt",header=F)
mat_data <- as.matrix(data)
v1 <- mat_data[,1]
v2 <- mat_data[,2]
relations<- data.frame(from=v1,to=v2)
g<-graph.data.frame(relations,directed=TRUE)
options(max.print=100000000)
degree1 <- V(g)[degree(g, mode = 'out')==1 & degree(g, mode = 'in')==1]
g1 <- delete_vertices(g,degree1)
degree2 <- V(g1)[degree(g1, mode = 'out')<3 & degree(g1, mode = 'in')<3]
g2 <- delete_vertices(g1,degree2)
degree3 <- V(g2)[degree(g2, mode = 'out')<4 & degree(g2, mode = 'in')<4]
g3 <- delete_vertices(g2,degree3)
vcount(g3)
```

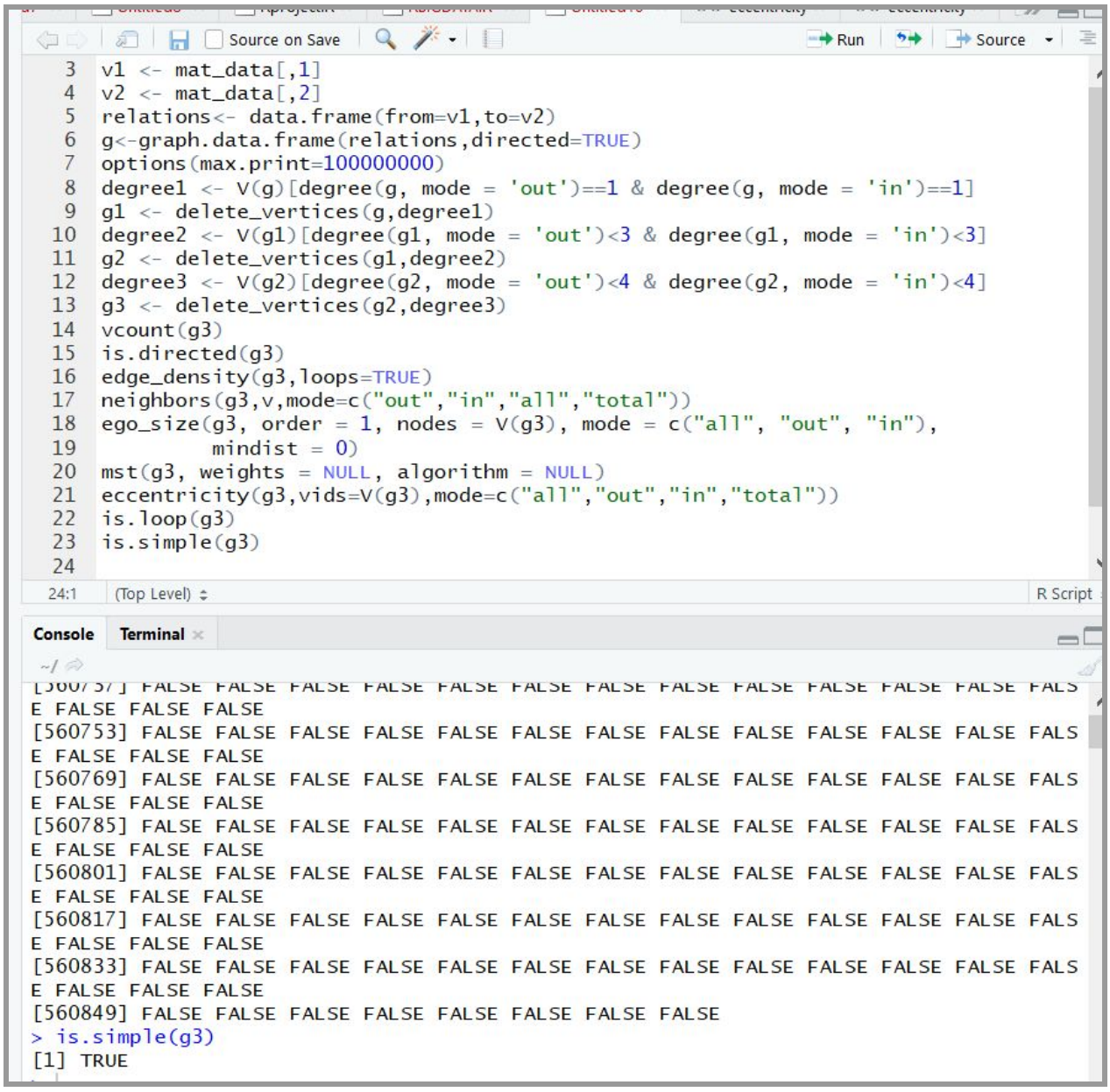
```
> data <- read.table("C:/Users/aneri/Downloads/roadNet-CA.txt",header=F)
> mat_data <- as.matrix(data)
> v1 <- mat_data[,1]
> v2 <- mat_data[,2]
> relations<- data.frame(from=v1,to=v2)
> g<-graph.data.frame(relations,directed=TRUE)
> degree1 <- V(g)[degree(g, mode = 'out')==1 & degree(g, mode = 'in')==1]
> g1 <- delete_vertices(g,degree1)
> degree2 <- V(g1)[degree(g1, mode = 'out')<3 & degree(g1, mode = 'in')<3]
> g2 <- delete_vertices(g1,degree2)
> degree3 <- V(g2)[degree(g2, mode = 'out')<4 & degree(g2, mode = 'in')<4]
> g3 <- delete_vertices(g2,degree3)
> vcount(g3)
[1] 290934
>
```

plot(g3)

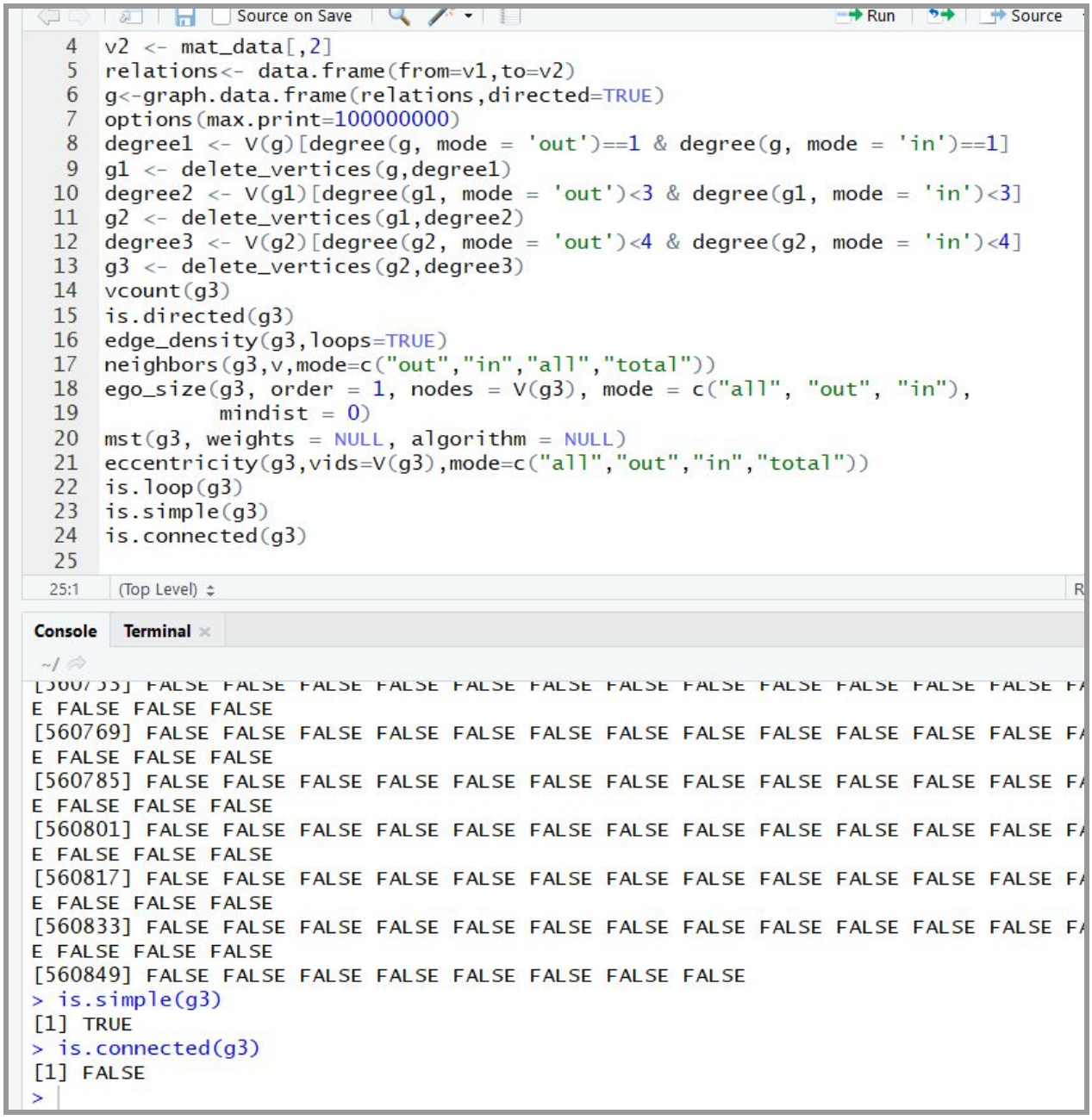


4. Experiment with at least 10 of the functions that I have shown in the lecture notes and associated PPT file on Blackboard.

1) is.simple(g3)

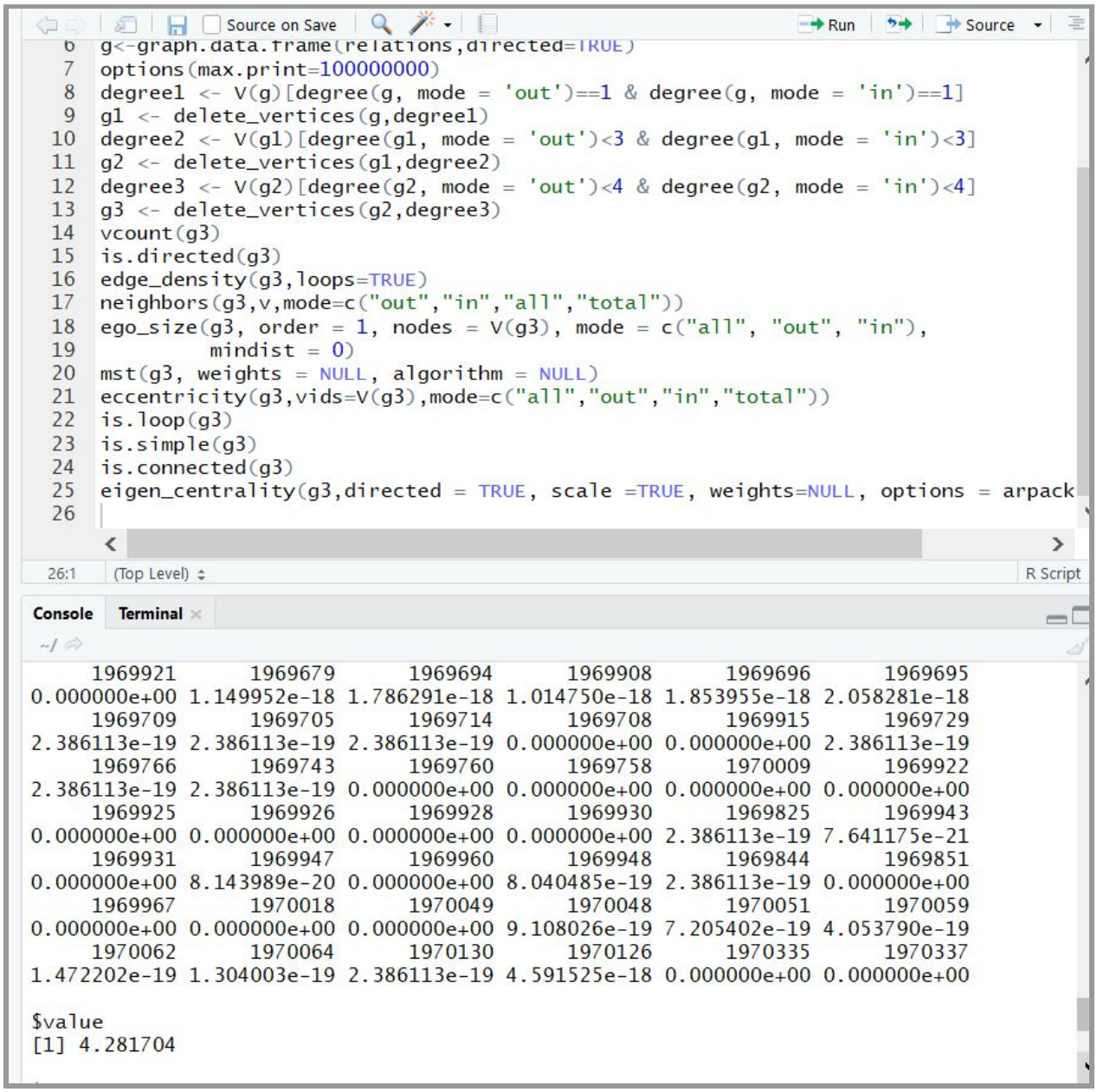


2) is.connected(g3)



3) Eigen Centrality

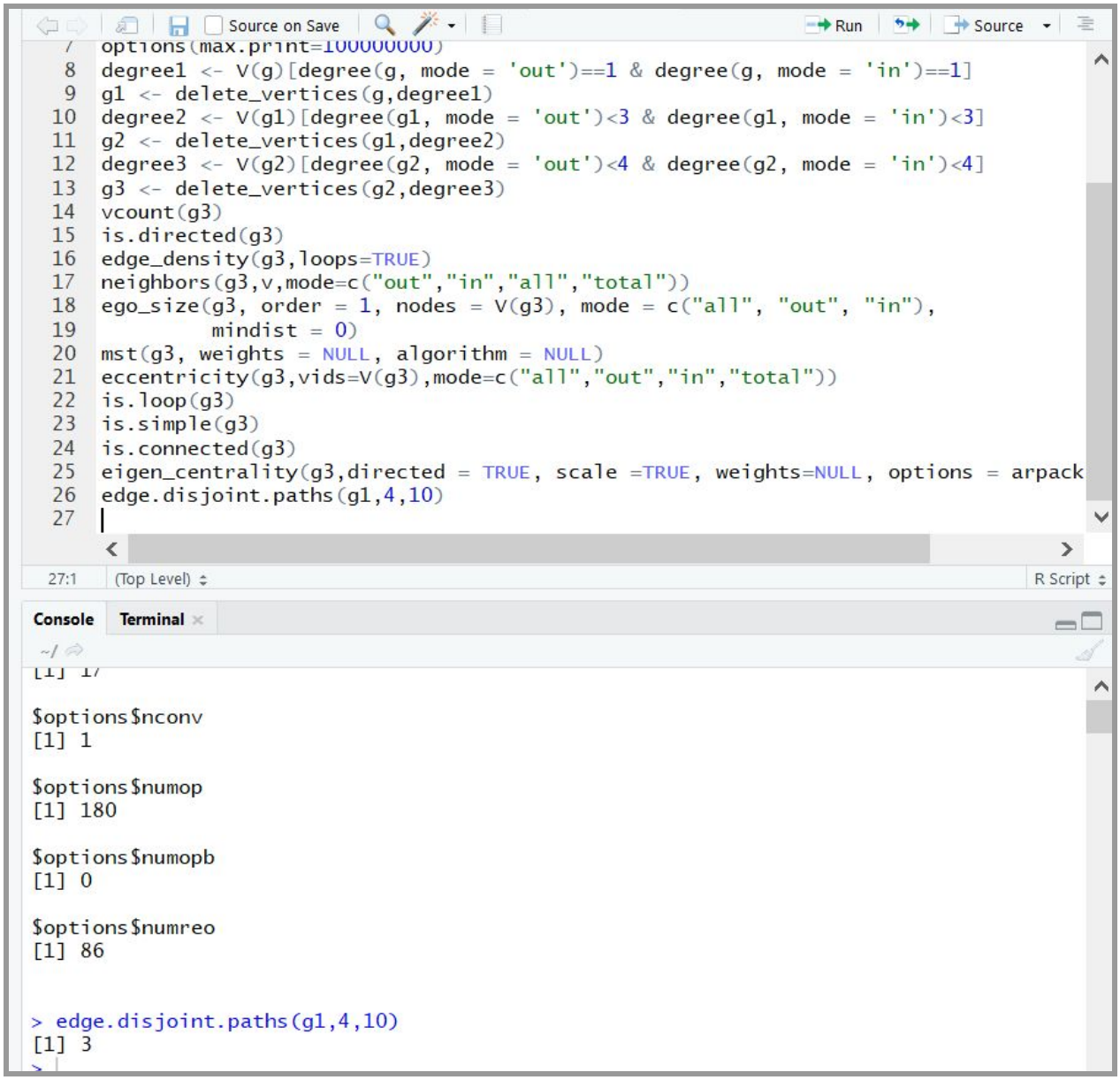
eigen_centrality(g3,directed = TRUE, scale =TRUE, weights=NULL, options = arpack_defaults)



```
g<-graph.data.frame(relations,directed=TRUE)
options(max.print=100000000)
degree1 <- V(g)[degree(g, mode = 'out')==1 & degree(g, mode = 'in')==1]
g1 <- delete_vertices(g,degree1)
degree2 <- V(g1)[degree(g1, mode = 'out')<3 & degree(g1, mode = 'in')<3]
g2 <- delete_vertices(g1,degree2)
degree3 <- V(g2)[degree(g2, mode = 'out')<4 & degree(g2, mode = 'in')<4]
g3 <- delete_vertices(g2,degree3)
vcount(g3)
is.directed(g3)
edge_density(g3,loops=TRUE)
neighbors(g3,v,mode=c("out","in","all","total"))
ego_size(g3, order = 1, nodes = V(g3), mode = c("all", "out", "in"),
         mindist = 0)
mst(g3, weights = NULL, algorithm = NULL)
eccentricity(g3,vids=V(g3),mode=c("all","out","in","total"))
is.loop(g3)
is.simple(g3)
is.connected(g3)
eigen_centrality(g3,directed = TRUE, scale =TRUE, weights=NULL, options = arpack
```

```
     1969921      1969679      1969694      1969908      1969696      1969695
0.000000e+00 1.149952e-18 1.786291e-18 1.014750e-18 1.853955e-18 2.058281e-18
     1969709      1969705      1969714      1969708      1969915      1969729
2.386113e-19 2.386113e-19 2.386113e-19 0.000000e+00 0.000000e+00 2.386113e-19
     1969766      1969743      1969760      1969758      1970009      1969922
2.386113e-19 2.386113e-19 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
     1969925      1969926      1969928      1969930      1969825      1969943
0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00 2.386113e-19 7.641175e-21
     1969931      1969947      1969960      1969948      1969844      1969851
0.000000e+00 8.143989e-20 0.000000e+00 8.040485e-19 2.386113e-19 0.000000e+00
     1969967      1970018      1970049      1970048      1970051      1970059
0.000000e+00 0.000000e+00 0.000000e+00 9.108026e-19 7.205402e-19 4.053790e-19
     1970062      1970064      1970130      1970126      1970335      1970337
1.472202e-19 1.304003e-19 2.386113e-19 4.591525e-18 0.000000e+00 0.000000e+00

$value
[1] 4.281704
```

4) edge.disjoint.paths(g1,4,10)



5) Pagerank:
page_rank(g3)

```
23  is.simple(g3)
24  is.connected(g3)
25  eigen_centrality(g3,directed = TRUE, scale =TRUE, weights=NULL, options = a
26  edge.disjoint.paths(g1,4,10)
27  matrix.df <- as.data.frame(mat_data)
28
29  degree4 <- V(g3)[ degree(g3, mode = 'in')==8]
30  max(degree4)
31  count(degree4)
32  head(degree4)
33  degree(g3, v = V(g3), (mode = "out" )==8)
34
35  V(g3)$name[degree(g3)==max(degree(g3))]
36  page_rank(g3)
37  pagerank <- page_rank(g3)
38  head(pagerank)
39
```

36:1 (Top Level) R Script

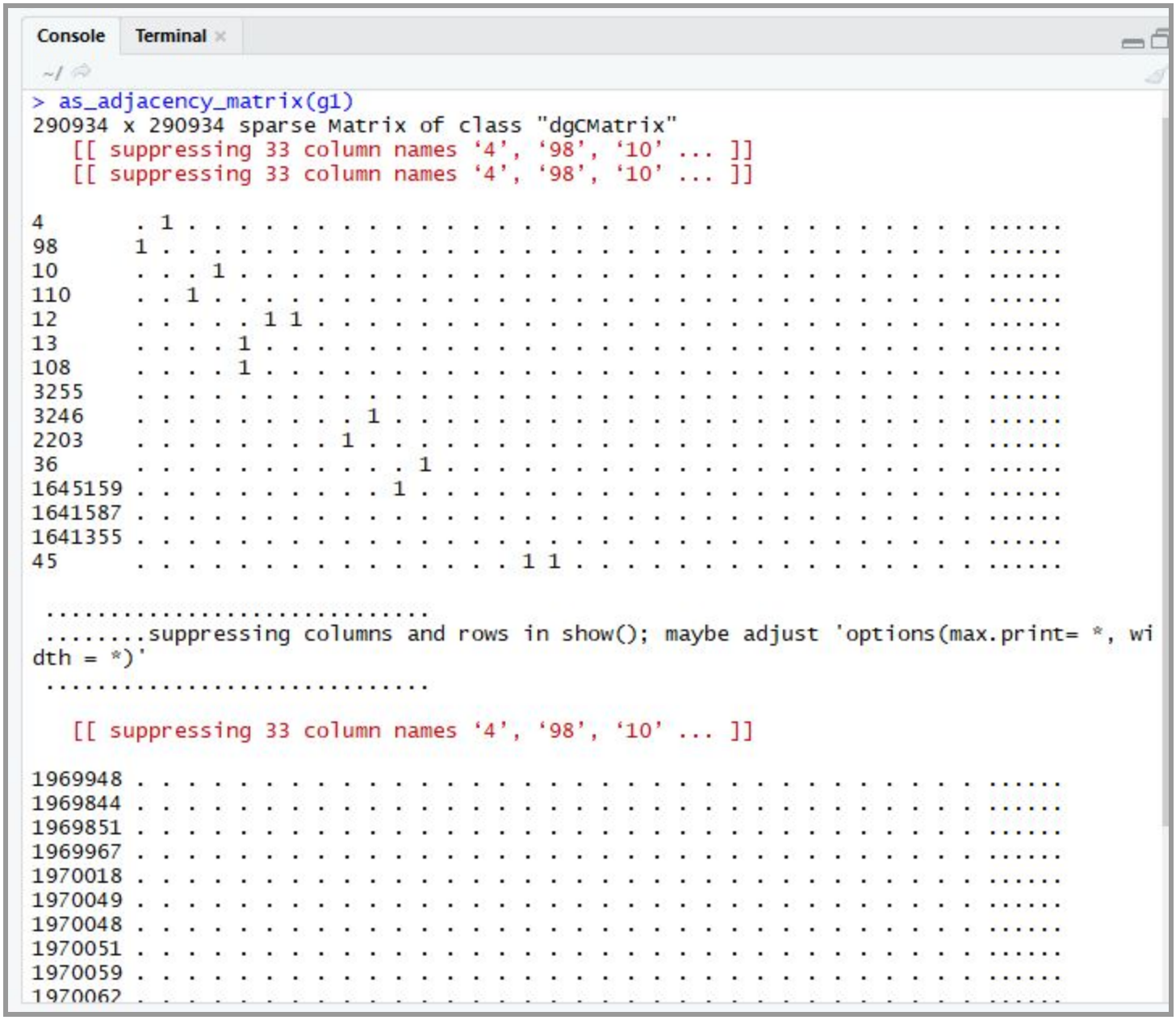
Console Terminal

```
3.901383e-06 3.909639e-06 5.333069e-06 2.037176e-06 3.061510e-06 5.829358e-07
     1969921      1969679      1969694      1969908      1969696      1969695
2.993454e-06 4.770203e-06 2.551472e-06 2.610272e-06 6.947775e-06 2.551472e-06
     1969709      1969705      1969714      1969708      1969915      1969729
5.829358e-07 5.829358e-07 5.829358e-07 2.993454e-06 5.671808e-06 5.829358e-07
     1969766      1969743      1969760      1969758      1970009      1969922
5.829358e-07 5.829358e-07 2.993454e-06 5.671808e-06 2.993454e-06 2.993454e-06
     1969925      1969926      1969928      1969930      1969825      1969943
5.671808e-06 2.993454e-06 3.686395e-06 5.351880e-06 5.829358e-07 3.994748e-06
     1969931      1969947      1969960      1969948      1969844      1969851
5.182253e-06 2.482604e-06 3.886239e-06 4.469807e-06 5.829358e-07 5.506860e-06
     1969967      1970018      1970049      1970048      1970051      1970059
3.727326e-06 2.099302e-06 2.421427e-06 4.325862e-06 3.964031e-06 3.629655e-06
     1970062      1970064      1970130      1970126      1970335      1970337
3.886239e-06 3.886239e-06 5.829358e-07 2.984718e-06 3.886239e-06 3.886239e-06

$value
[1] 1
```

6) Vertex Attribute:
vertex_attr(g3)

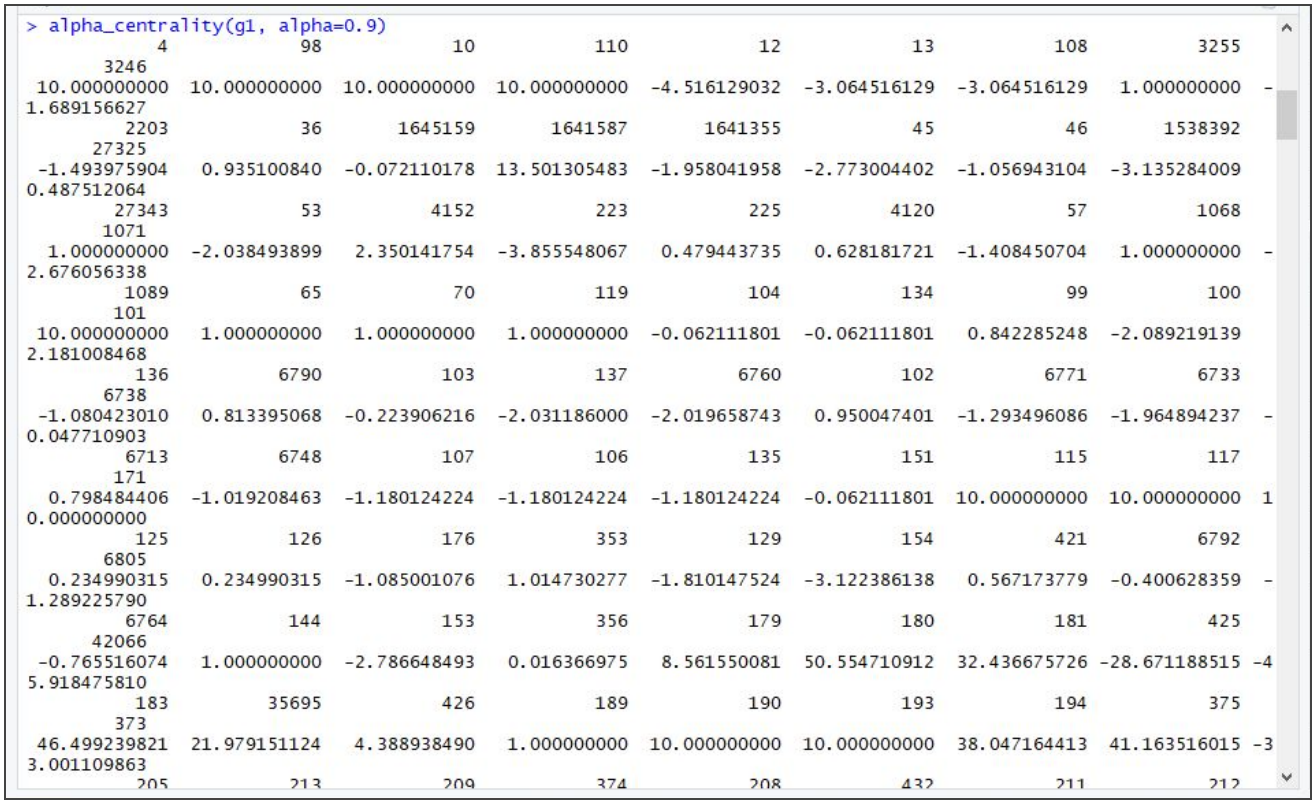
```
> vertex_attr(g1)
$name
   [1] "4"        "98"       "10"       "110"      "12"       "13"       "108"
   [8] "3255"     "3246"     "2203"     "36"       "1645159"  "1641587"  "1641355"
  [15] "45"       "46"       "1538392"  "27325"    "27343"    "53"       "4152"
  [22] "223"      "225"      "4120"     "57"       "1068"     "1071"     "1089"
  [29] "65"       "70"       "119"      "104"      "134"      "99"       "100"
  [36] "101"      "136"      "6790"     "103"      "137"      "6760"     "102"
  [43] "6771"     "6733"     "6738"     "6713"     "6748"     "107"      "106"
  [50] "135"      "151"      "115"      "117"      "171"      "125"      "126"
  [57] "176"      "353"      "129"      "154"      "421"      "6792"     "6805"
  [64] "6764"     "144"      "153"      "356"      "179"      "180"      "181"
  [71] "425"      "42066"    "183"      "35695"    "426"      "189"      "190"
  [78] "193"      "194"      "375"      "373"      "205"      "213"      "209"
  [85] "374"      "208"      "432"      "211"      "212"      "222"      "221"
  [92] "7901"     "7918"     "224"      "3937"     "4114"     "4148"     "260"
  [99] "250"      "238"      "239"      "3276"     "258"      "259"      "35851"
 [106] "285"      "284"      "287"      "35846"    "35796"    "42582"    "35863"
 [113] "1092"     "321"      "322"      "323"      "326"      "324"      "325"
 [120] "3479"     "3432"     "3430"     "3431"     "3475"     "3480"     "4175"
 [127] "4181"     "4173"     "346"      "347"      "349"      "3285"     "3319"
 [134] "3339"     "359"      "460"      "7162"     "42094"    "7163"     "3263"
 [141] "457"      "407"      "409"      "6025"     "5636"     "413"      "7757"
 [148] "7794"     "6793"     "429"      "430"      "439"      "438"      "33468"
 [155] "20655"    "23896"    "458"      "41945"    "20812"    "42074"    "464"
 [162] "467"      "20571"    "465"      "25505"    "4074"     "5809"     "5951"
 [169] "4077"     "7131"     "7154"     "7145"     "7142"     "501"      "7141"
 [176] "7164"     "7165"     "511"      "6685"     "6681"     "512"      "6684"
 [183] "6696"     "6683"     "516"      "1119"     "5884"     "5894"     "518"
 [190] "519"      "520"      "8155"     "8145"     "8153"     "528"      "534"
 [197] "5421"     "5444"     "5438"     "5433"     "538"      "1603443"  "4371"
 [204] "4373"     "4481"     "554"      "560"      "585"      "2652"     "597"
 [211] "7066"     "600"      "601"      "3470"     "3484"     "3498"     "664"
```

7) Adjacency Matrix:
as_adjacency_matrix(g3)



8) Alpha centrality:

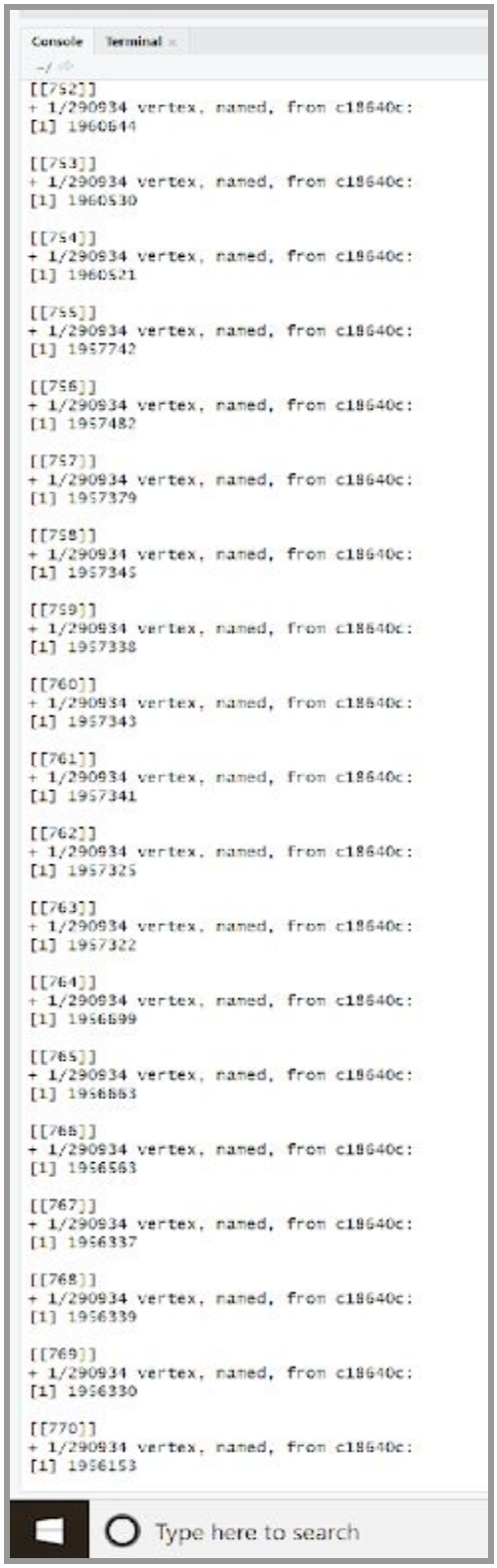
alpha_centrality(g3,alpha=0.9)



```
> alpha_centrality(g1, alpha=0.9)
           4           98           10          110           12           13          108         3255
      3246
 10.000000000 10.000000000 10.000000000 10.000000000 -4.516129032 -3.064516129 -3.064516129  1.000000000 -
1.689156627
        2203           36      1645159      1641587      1641355           45           46      1538392
     27325
 -1.493975904  0.935100840 -0.072110178 13.501305483 -1.958041958 -2.773004402 -1.056943104 -3.135284009
0.487512064
       27343           53         4152          223          225         4120           57         1068
      1071
  1.000000000 -2.038493899  2.350141754 -3.855548067  0.479443735  0.628181721 -1.408450704  1.000000000 -
2.676056338
        1089           65           70          119          104          134           99          100
       101
 10.000000000  1.000000000  1.000000000  1.000000000 -0.062111801 -0.062111801  0.842285248 -2.089219139
2.181008468
         136         6790          103          137         6760          102         6771         6733
      6738
 -1.080423010  0.813395068 -0.223906216 -2.031186000 -2.019658743  0.950047401 -1.293496086 -1.964894237 -
0.047710903
        6713         6748          107          106          135          151          115          117
       171
  0.798484406 -1.019208463 -1.180124224 -1.180124224 -1.180124224 -0.062111801 10.000000000 10.000000000  1
0.000000000
         125          126          176          353          129          154          421         6792
      6805
  0.234990315  0.234990315 -1.085001076  1.014730277 -1.810147524 -3.122386138  0.567173779 -0.400628359 -
1.289225790
        6764          144          153          356          179          180          181          425
     42066
 -0.765516074  1.000000000 -2.786648493  0.016366975  8.561550081 50.554710912 32.436675726 -28.671188515 -4
5.918475810
         183        35695          426          189          190          193          194          375
       373
 46.499239821 21.979151124  4.388938490  1.000000000 10.000000000 10.000000000 38.047164413 41.163516015 -3
3.001109863
         205          213          209          374          208          432          211          212
```

9) Cliques:

cliques(g3)



10) Weight

E(g1)$weight<-rnorm(ecount(g1))
V(g1)$weight<-rnorm(vcount(g1))
g1

```
> E(g1)$weight<-rnorm(ecount(g1))
> V(g1)$weight<-rnorm(vcount(g1))
> g1
IGRAPH c40d13a DNW- 290934 560856 --
+ attr: name (v/c), weight (v/n), weight (e/n)
+ edges from c40d13a (vertex names):
 [1] 4      ->98      98     ->4       10     ->110     110    ->10      12     ->13

 [6] 12     ->108     13     ->12      108    ->12      3246   ->2203    3246   ->3257

[11] 2203   ->2146    2203   ->3246    36     ->1645159 1645159->36      1645159->16451
56
[16] 1645159->1645157 1645159->1648644 1641587->1633418 1641587->1641606 1641355->16289
54
[21] 1641355->1639780 45     ->46      45     ->1538392 46     ->45      46     ->27325

[26] 1538392->45      1538392->1538391 27325  ->46      27325  ->27335   53     ->223

[31] 53     ->225     4152   ->4148    4152   ->4153    4152   ->4156    223    ->53

[36] 223    ->224     223    ->3937    225    ->53      225    ->224     225    ->4114
```

5. Explore other functions in the igraph package – at least 15 of them not shown in the lecture notes.

1) is.directed(g3)

```
mat_data <- as.matrix(data)
v1 <- mat_data[,1]
v2 <- mat_data[,2]
relations<- data.frame(from=v1,to=v2)
g<-graph.data.frame(relations,directed=TRUE)
options(max.print=100000000)
degree1 <- V(g)[degree(g, mode = 'out')==1 & degree(g, mode = 'in')==1]
g1 <- delete_vertices(g,degree1)
degree2 <- V(g1)[degree(g1, mode = 'out')<3 & degree(g1, mode = 'in')<3]
g2 <- delete_vertices(g1,degree2)
degree3 <- V(g2)[degree(g2, mode = 'out')<4 & degree(g2, mode = 'in')<4]
g3 <- delete_vertices(g2,degree3)
vcount(g3)
is.directed(g3)
```

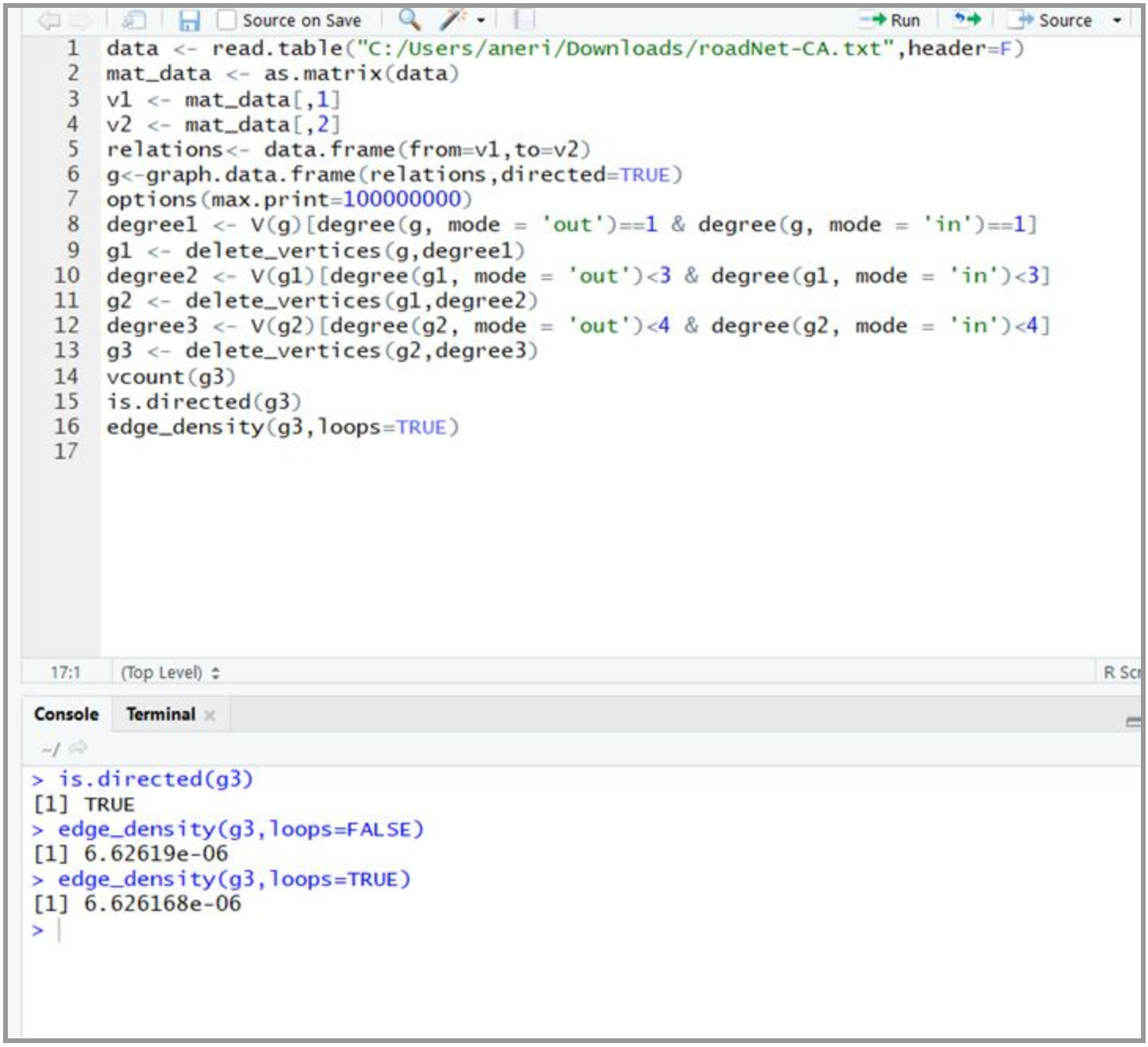
15:16 (Top Level) R Script

Console Terminal

```
> is.directed(g3)
[1] TRUE
>
```

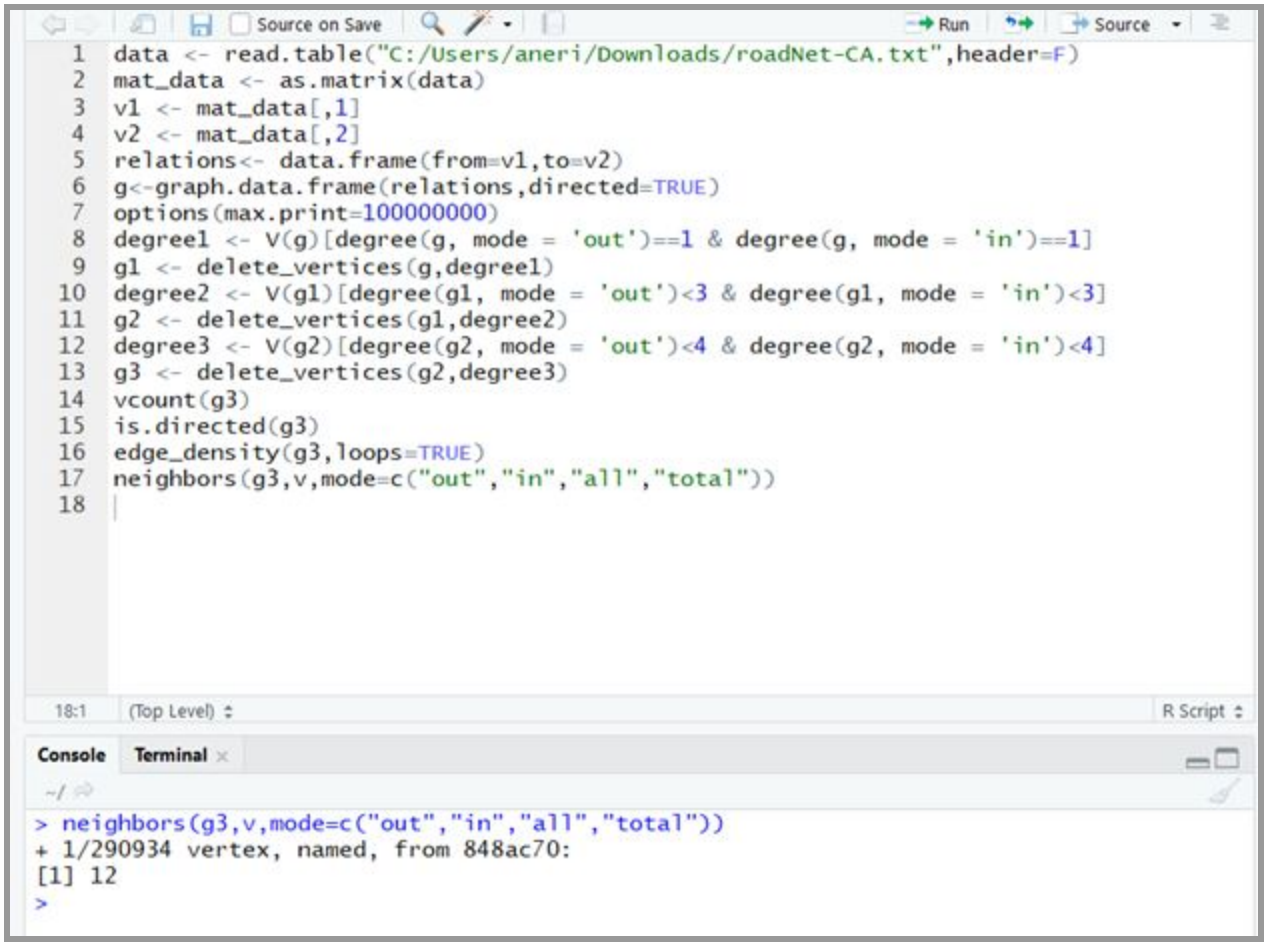
2) Edge_density

edge_density(g3,loops=FALSE)
edge_density(g3,loops=TRUE))



3) Neighbors

neighbors(g3,v,mode=c(“in”,”out”,”total”,”all”)



4) Ego Size

ego_size(g3, order = 1, nodes = V(g3), mode = c("all", "out", "in"), mindist = 0)

```
mat_data <- as.matrix(data)
v1 <- mat_data[,1]
v2 <- mat_data[,2]
relations<- data.frame(from=v1,to=v2)
g<-graph.data.frame(relations,directed=TRUE)
options(max.print=100000000)
degree1 <- V(g)[degree(g, mode = 'out')==1 & degree(g, mode = 'in')==1]
g1 <- delete_vertices(g,degree1)
degree2 <- V(g1)[degree(g1, mode = 'out')<3 & degree(g1, mode = 'in')<3]
g2 <- delete_vertices(g1,degree2)
degree3 <- V(g2)[degree(g2, mode = 'out')<4 & degree(g2, mode = 'in')<4]
g3 <- delete_vertices(g2,degree3)
vcount(g3)
is.directed(g3)
edge_density(g3,loops=TRUE)
neighbors(g3,v,mode=c("out","in","all","total"))
ego_size(g3, order = 1, nodes = V(g3), mode = c("all", "out", "in"),
         mindist = 0)
```

20:1 (Top Level) R Script

Console Terminal

```
2 2 3 2 2 3 4 2 3 2
[290641] 2 2 1 2 3 2 3 2 2 1 4 4 4 4 5 4 4 2 2 2 2 1 4 2 5 2 1 2 4 1 3 4 2 4 5 5 4 3
2 3 3 2 2 3 3 3 4 5
[290689] 2 3 1 4 4 2 1 3 4 3 3 3 3 3 3 3 4 5 3 3 3 3 3 3 5 5 4 3 5 2 3 5 3 3 4 3 2 3
3 2 2 2 3 5 3 4 1 4
[290737] 2 4 4 3 4 3 1 3 2 4 4 5 3 4 4 4 3 3 2 3 2 2 2 2 3 4 1 3 5 3 3 3 2 1 3 3 5 3
1 1 3 4 2 1 3 1 4 3
[290785] 4 1 2 1 2 4 3 4 3 3 4 3 3 3 3 3 3 3 3 3 1 3 4 4 3 3 2 3 3 3 3 3 3 3 3 2 2
4 3 3 4 4 3 3 2 2 4
[290833] 1 4 5 3 2 3 4 5 5 3 5 3 2 4 4 5 3 5 4 3 3 6 4 4 5 4 5 4 3 5 4 4 3 4 2 4 4 1
2 4 3 3 3 3 5 4 5 3
[290881] 5 4 3 3 3 4 4 4 5 2 3 1 2 3 2 2 4 2 1 1 1 2 3 1 1 1 2 3 2 2 3 2 3 4 1 3 4 2
2 3 1 4 3 2 2 3 3 3
[290929] 2 2 1 3 2 2
>
```

5) Minimum Spanning Tree

mst(g3, weights = NULL, algorithm = NULL)

```
mat_data <- as.matrix(data)
v1 <- mat_data[,1]
v2 <- mat_data[,2]
relations<- data.frame(from=v1,to=v2)
g<-graph.data.frame(relations,directed=TRUE)
options(max.print=100000000)
degree1 <- V(g)[degree(g, mode = 'out')==1 & degree(g, mode = 'in')==1]
g1 <- delete_vertices(g,degree1)
degree2 <- V(g1)[degree(g1, mode = 'out')<3 & degree(g1, mode = 'in')<3]
g2 <- delete_vertices(g1,degree2)
degree3 <- V(g2)[degree(g2, mode = 'out')<4 & degree(g2, mode = 'in')<4]
g3 <- delete_vertices(g2,degree3)
vcount(g3)
is.directed(g3)
edge_density(g3,loops=TRUE)
neighbors(g3,v,mode=c("out","in","all","total"))
ego_size(g3, order = 1, nodes = V(g3), mode = c("all", "out", "in"),
         mindist = 0)
mst(g3, weights = NULL, algorithm = NULL)
```

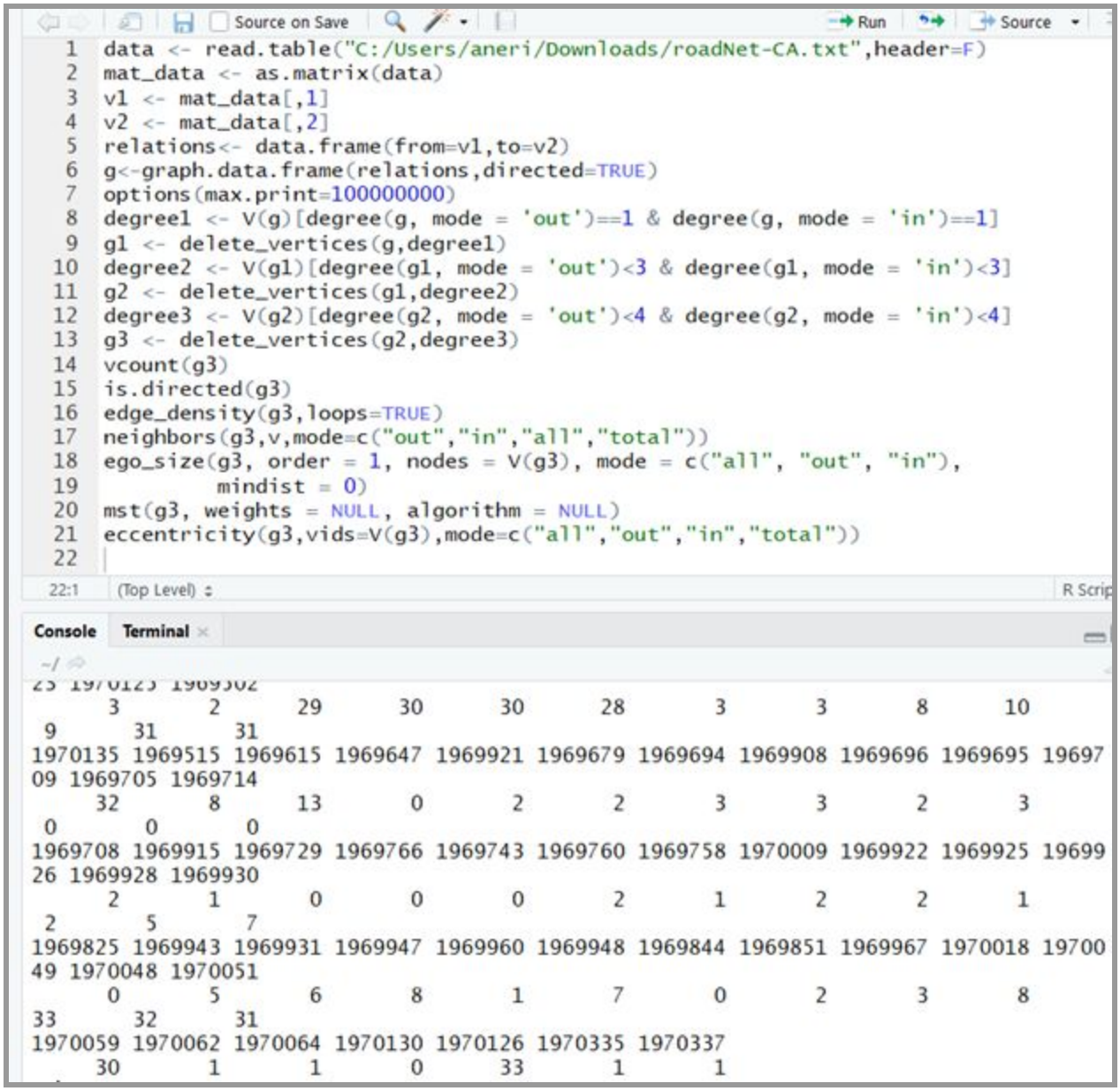
20:42 (Top Level) R Script

Console Terminal

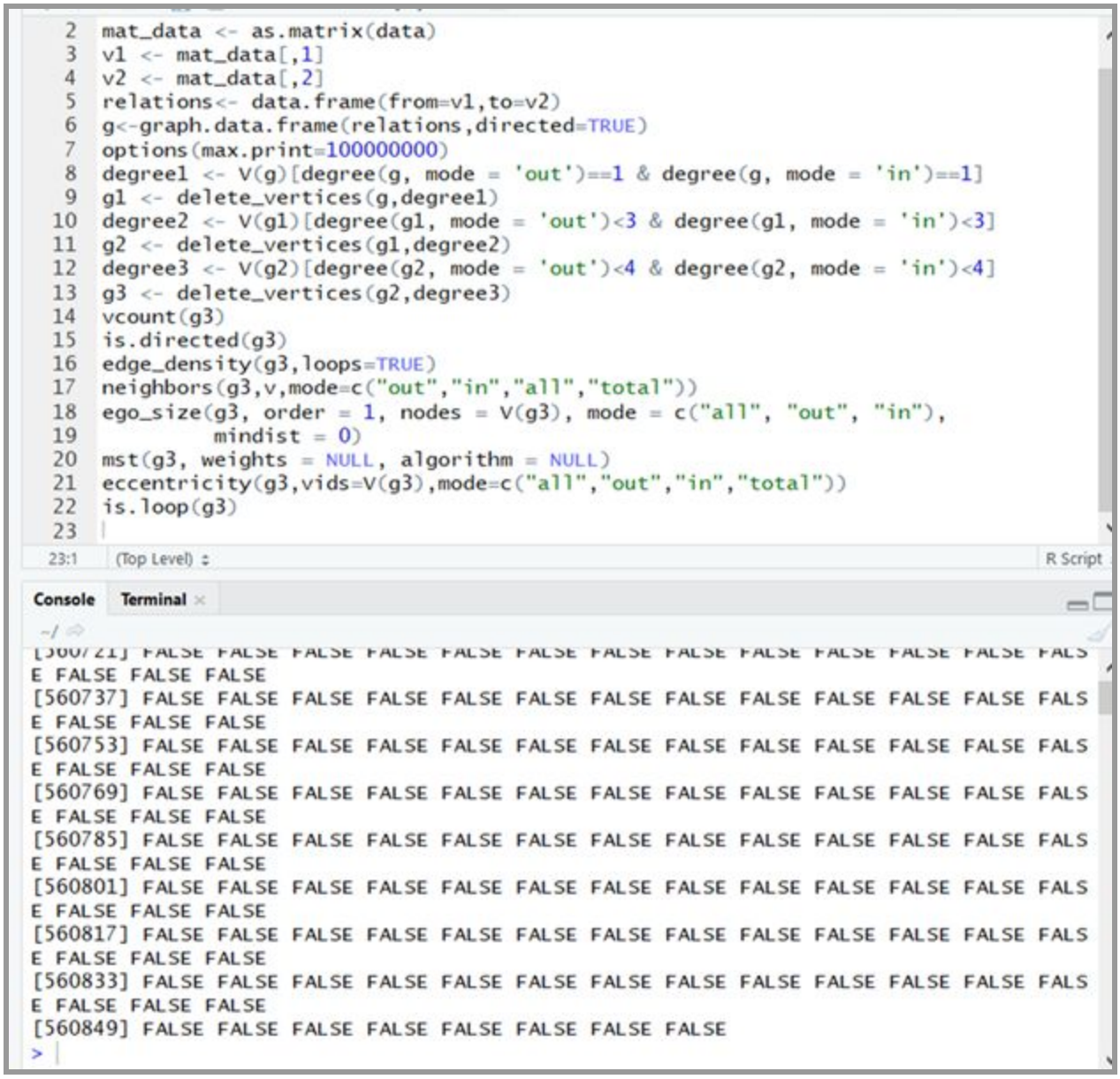
```
+ attr: name (v/c)
+ edges from 07a9387 (vertex names):
 [1] 4       ->98       10      ->110      12      ->13       12      ->108      3246    ->220
3
 [6] 3246    ->3257     2203    ->2146     36      ->1645159  1645159->1645156  1645159->164
5157
[11] 1645159->1648644  1641587->1633418  1641587->1641606  1641355->1628954  1641355->163
9780
[16] 45      ->46       45      ->1538392  46      ->27325    1538392->1538391  27325   ->273
35
[21] 53      ->223      53      ->225      4152    ->4156     223     ->224      223     ->393
7
[26] 225     ->4114     225     ->4148     4120    ->4153     4120    ->4154     57      ->107
1
[31] 1071    ->1070     1089    ->171      104     ->107      99      ->101      99      ->136

[36] 99      ->6790     100     ->99       100     ->103      100     ->137      101     ->677
1
```

6) Eccentricity

eccentricity(g3,vids=V(g3),mode=c("all","out","in","total"))



7) is.loop(g3)



```
mat_data <- as.matrix(data)
v1 <- mat_data[,1]
v2 <- mat_data[,2]
relations<- data.frame(from=v1,to=v2)
g<-graph.data.frame(relations,directed=TRUE)
options(max.print=100000000)
degree1 <- V(g)[degree(g, mode = 'out')==1 & degree(g, mode = 'in')==1]
g1 <- delete_vertices(g,degree1)
degree2 <- V(g1)[degree(g1, mode = 'out')<3 & degree(g1, mode = 'in')<3]
g2 <- delete_vertices(g1,degree2)
degree3 <- V(g2)[degree(g2, mode = 'out')<4 & degree(g2, mode = 'in')<4]
g3 <- delete_vertices(g2,degree3)
vcount(g3)
is.directed(g3)
edge_density(g3,loops=TRUE)
neighbors(g3,v,mode=c("out","in","all","total"))
ego_size(g3, order = 1, nodes = V(g3), mode = c("all", "out", "in"),
         mindist = 0)
mst(g3, weights = NULL, algorithm = NULL)
eccentricity(g3,vids=V(g3),mode=c("all","out","in","total"))
is.loop(g3)
```

```
23:1  (Top Level)                                                R Script

Console  Terminal
~/
[560721] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALS
E FALSE FALSE FALSE
[560737] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALS
E FALSE FALSE FALSE
[560753] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALS
E FALSE FALSE FALSE
[560769] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALS
E FALSE FALSE FALSE
[560785] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALS
E FALSE FALSE FALSE
[560801] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALS
E FALSE FALSE FALSE
[560817] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALS
E FALSE FALSE FALSE
[560833] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALS
E FALSE FALSE FALSE
[560849] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
>
```

8) diameter

A network diameter is the longest geodesic distance (length of the shortest path between two nodes) in the network. The result indicates the number of nodes along the path.

```
> diameter(g3, directed = TRUE)
[1] 416
```

9) get_diameter

Returns the nodes along the first path found in the network with the longest geodesic distance. The result is a vertex sequence.

```
> diam <- get_diameter(g3)
> diam
+ 417/290934 vertices, named, from 92007aa:
  [1] 515136 515137 515138 515124 515119 514997 534895
  [8] 534503 534502 514966 514965 534892 514991 534890
 [15] 534889 534855 532317 514940 534853 514915 506303
 [22] 505950 534849 505959 534874 534873 534840 534876
 [29] 505933 505932 534870 505902 505901 534857 505997
 [36] 505170 505008 505009 505011 505167 505179 505178
 [43] 505184 505182 505186 505185 505730 505743 505744
 [50] 505751 505752 505749 505754 505717 505701 505719
 [57] 505820 505714 505711 505707 505692 504695 504696
 [64] 505685 505682 505680 505649 505644 505642 505639
+ ... omitted several vertices
```

10) hub_score

Hubs are generally used to examine web pages containing a large number of outgoing links. The result displays the hub score of each vertex.

```
> hub_score(g3, scale = TRUE)
$vector
           4           98           10          110           12           13
1.779357e-16 1.779357e-16 1.779357e-16 1.779357e-16 8.625324e-17 4.312662e-17
         108         3255         3246         2203           36      1645159
4.312662e-17 0.000000e+00 2.095981e-16 4.078202e-16 0.000000e+00 0.000000e+00
     1641587      1641355           45           46      1538392        27325
0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
       27343           53         4152          223          225         4120
0.000000e+00 5.655526e-16 9.424399e-16 6.432512e-16 1.118045e-15 4.137488e-16
          57         1068         1071         1089           65           70
0.000000e+00 0.000000e+00 0.000000e+00 1.779357e-16 0.000000e+00 0.000000e+00
         119          104          134           99          100          101
0.000000e+00 0.000000e+00 0.000000e+00 5.498508e-15 4.610829e-15 5.425069e-15
         136         6790          103          137         6760          102
5.812587e-15 5.605652e-15 3.237296e-15 4.927670e-15 2.730909e-15 4.325552e-15
        6771         6733         6738         6713         6748          107
6.113392e-15 1.375330e-15 6.805932e-15 7.134937e-16 1.635621e-15 1.445901e-15
         106          135          151          115          117          171
1.446062e-15 1.445900e-15 0.000000e+00 1.779357e-16 1.779357e-16 1.779357e-16
         125          126          176          353          129          154
1.194685e-16 1.194685e-16 0.000000e+00 0.000000e+00 0.000000e+00 8.694271e-17
         421         6792         6805         6764          144          153
4.026211e-15 4.143359e-15 3.887047e-15 3.342207e-15 0.000000e+00 0.000000e+00
```

11) betweenness

This function returns the number of geodesics passing through a node, hence indicating its centrality in the network.

```
> betweenness(g3, v = V(g3), directed = TRUE)
           4           98           10          110           12           13
0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00 2.000000e+00 0.000000e+00
         108         3255         3246         2203           36      1645159
0.000000e+00 0.000000e+00 2.000000e+00 4.000000e+00 0.000000e+00 1.833333e+01
     1641587      1641355           45           46      1538392        27325
1.000000e+00 6.000000e+00 2.800000e+01 3.600000e+01 1.600000e+01 4.000000e+01
       27343           53         4152          223          225         4120
0.000000e+00 6.948056e+02 5.415216e+04 2.471412e+03 3.740853e+04 7.781860e+03
          57         1068         1071         1089           65           70
0.000000e+00 0.000000e+00 4.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
         119          104          134           99          100          101
0.000000e+00 0.000000e+00 0.000000e+00 1.738478e+05 3.115911e+05 1.605799e+04
         136         6790          103          137         6760          102
4.123721e+04 1.528893e+05 2.392165e+05 5.437765e+04 4.409269e+05 2.405678e+05
        6771         6733         6738         6713         6748          107
1.074170e+04 9.731864e+04 1.870769e+05 0.000000e+00 1.154737e+05 8.000000e+00
         106          135          151          115          117          171
8.000000e+00 8.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
```

(remaining vertices not displayed)

12) mean_distance

This function displays the mean of the shortest distances between every pair of nodes in the network.

```
> mean_distance(g3, directed = TRUE)
[1] 98.23975
```

13) which_multiple

This function returns if any of the vertices have an loop or multiple edge. Since we are using a simplified graph, the function should return FALSE for all the vertices.

```
> which_multiple(g1, eids = E(g1))
   [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FA
LSE FALSE
  [16] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FA
LSE FALSE
  [31] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FA
LSE FALSE
  [46] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FA
LSE FALSE
  [61] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FA
LSE FALSE
  [76] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FA
LSE FALSE
  [91] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FA
LSE FALSE
 [106] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FA
LSE FALSE
 [121] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FA
LSE FALSE
 [136] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FA
LSE FALSE
 [151] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FA
LSE FALSE
```

(remaining vertices not displayed)

14) are_adjacent

This function returns TRUE if two vertices are adjacent to one another and FALSE otherwise.

```
> are_adjacent(g1, 1, 2)
[1] TRUE
>
```

15) shortest_paths

This function returns the shortest path between two vertices.

```
> shortest_paths(g, 1, 8)
$vpath
$vpath[[1]]
+ 5/1231291 vertices, named, from c390685:
[1] 0   469 380 183 422


$epath
NULL

$predecessors
NULL

$inbound_edges
NULL

>
```

Here, vertex 1 is 0 and vertex 8 is 422

Name	Type	Value
g	list [10] (S3: igraph)	List of length 10
[[1]]	list [1]	List of length 1
0	integer [2] (S3: igraph.vs)	2 3
[[2]]	list [1]	List of length 1
[[3]]	list [1]	List of length 1
[[4]]	list [1]	List of length 1
[[5]]	list [1]	List of length 1
[[6]]	list [1]	List of length 1
[[7]]	list [1]	List of length 1
[[8]]	list [1]	List of length 1
422	integer [3] (S3: igraph.vs)	5 208 214
[[9]]	list [1]	List of length 1

6. Determine the

(a) central person(s) in the graph,
(b) longest path,
(c) largest clique,
(d) ego, and
(e) betweenness centrality and power centrality.

a. Is there more than one person with the most degrees?

Yes, there are more than one person with the most degrees. It is "291797" and "534751". We used the function V(g3)$name[degree(g3)==max(degree(g3))] to find the people with the most degrees.

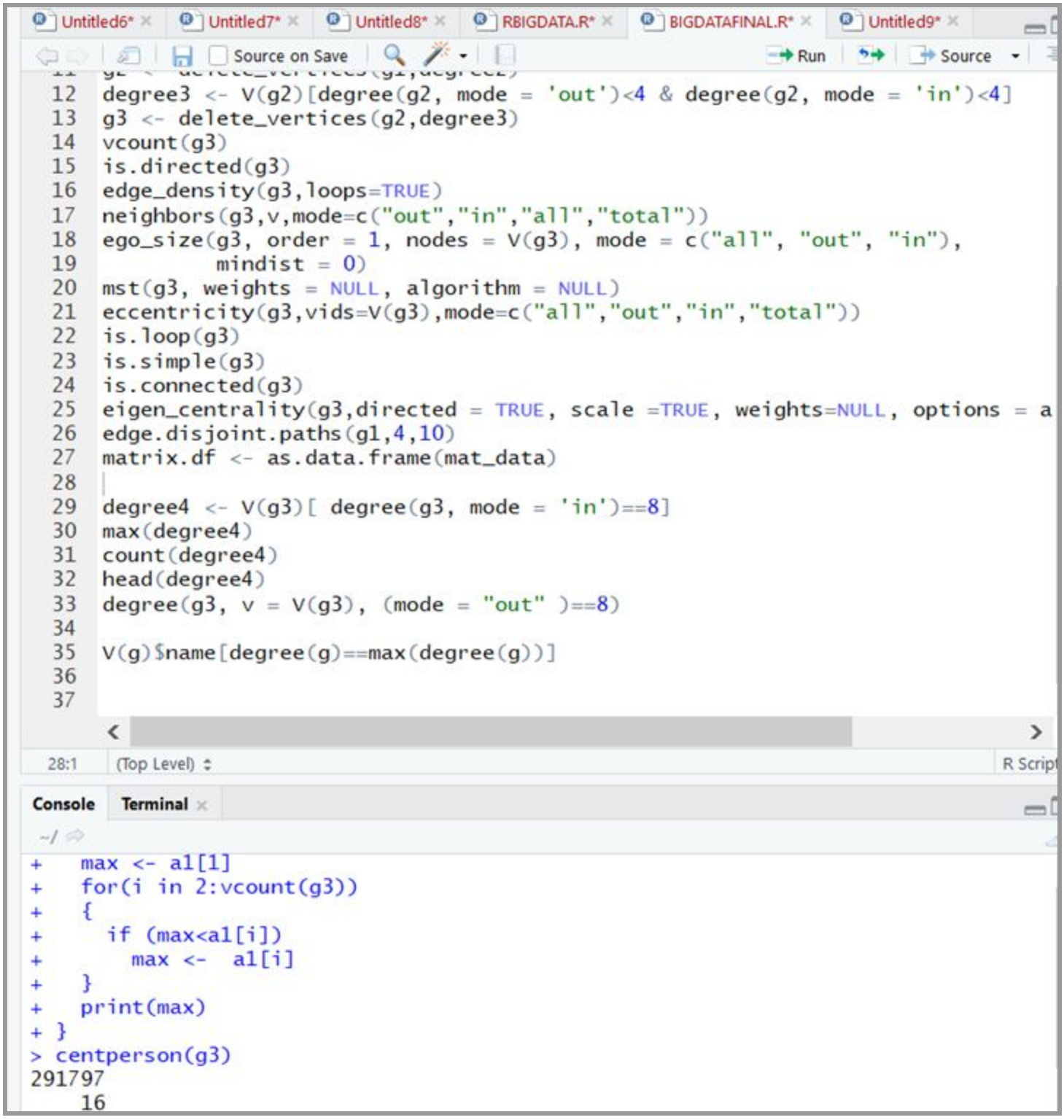
The central person in the graph is the one which has the most degree.The central person will be the person with most number of edges. In degree and out degree.

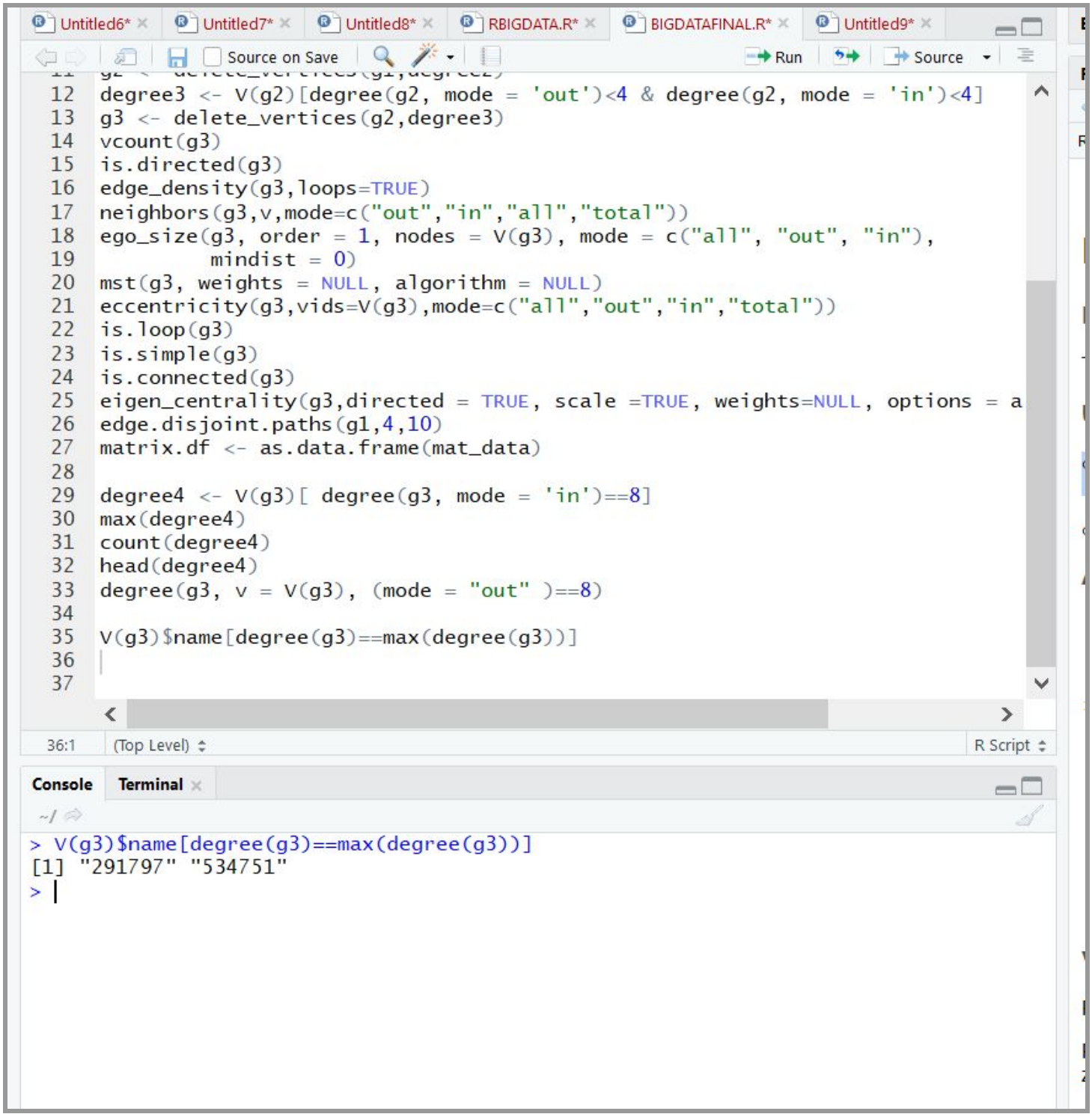
```
centperson <- function(g3) {
  a1 <- degree(g3) #it stores the degree of all vertices in g3
  max <- a1[1]   #a1[1] has the degree of node 1
  for(i in 2:vcount(g3)) #we will iterate from 2 to the vcount(g3) which will the last count
  {
    if (max<a1[i]) #this will help us in finding the maximum of the degree node
      max <-  a1[i] #this will substitute the value of it
}
  print(max) #prints the max value
}
```

The above is the code which is used for finding the central person in the graph

Alternatively, we can also use to find the number of multiple nodes with largest degree.

V(g3)$name[degree(g3)==max(degree(g3))]




Untitled6*
Untitled7*
Untitled8*
RBIGDATA.R*
BIGDATAFINAL.R*
Untitled9*
Source on Save
Run
Source
degree3 <- V(g2)[degree(g2, mode = 'out')<4 & degree(g2, mode = 'in')<4]
g3 <- delete_vertices(g2,degree3)
vcount(g3)
is.directed(g3)
edge_density(g3,loops=TRUE)
neighbors(g3,v,mode=c("out","in","all","total"))
ego_size(g3, order = 1, nodes = V(g3), mode = c("all", "out", "in"),
mindist = 0)
mst(g3, weights = NULL, algorithm = NULL)
eccentricity(g3,vids=V(g3),mode=c("all","out","in","total"))
is.loop(g3)
is.simple(g3)
is.connected(g3)
eigen_centrality(g3,directed = TRUE, scale =TRUE, weights=NULL, options = a
edge.disjoint.paths(g1,4,10)
matrix.df <- as.data.frame(mat_data)
degree4 <- V(g3)[degree(g3, mode = 'in')==8]
max(degree4)
count(degree4)
head(degree4)
degree(g3, v = V(g3), (mode = "out")==8)
V(g3)$name[degree(g3)==max(degree(g3))]
36:1
(Top Level)
R Script
Console
Terminal
> V(g3)$name[degree(g3)==max(degree(g3))]
[1] "291797" "534751"
>

b. Are there multiple longest paths?

Yes, there are multiple longest paths. The longest path distance we got is 416 between two nodes. Diameter is the length of the longest path between two nodes. We use get_diameter to identify this path

We use the following functions to find our longest path:

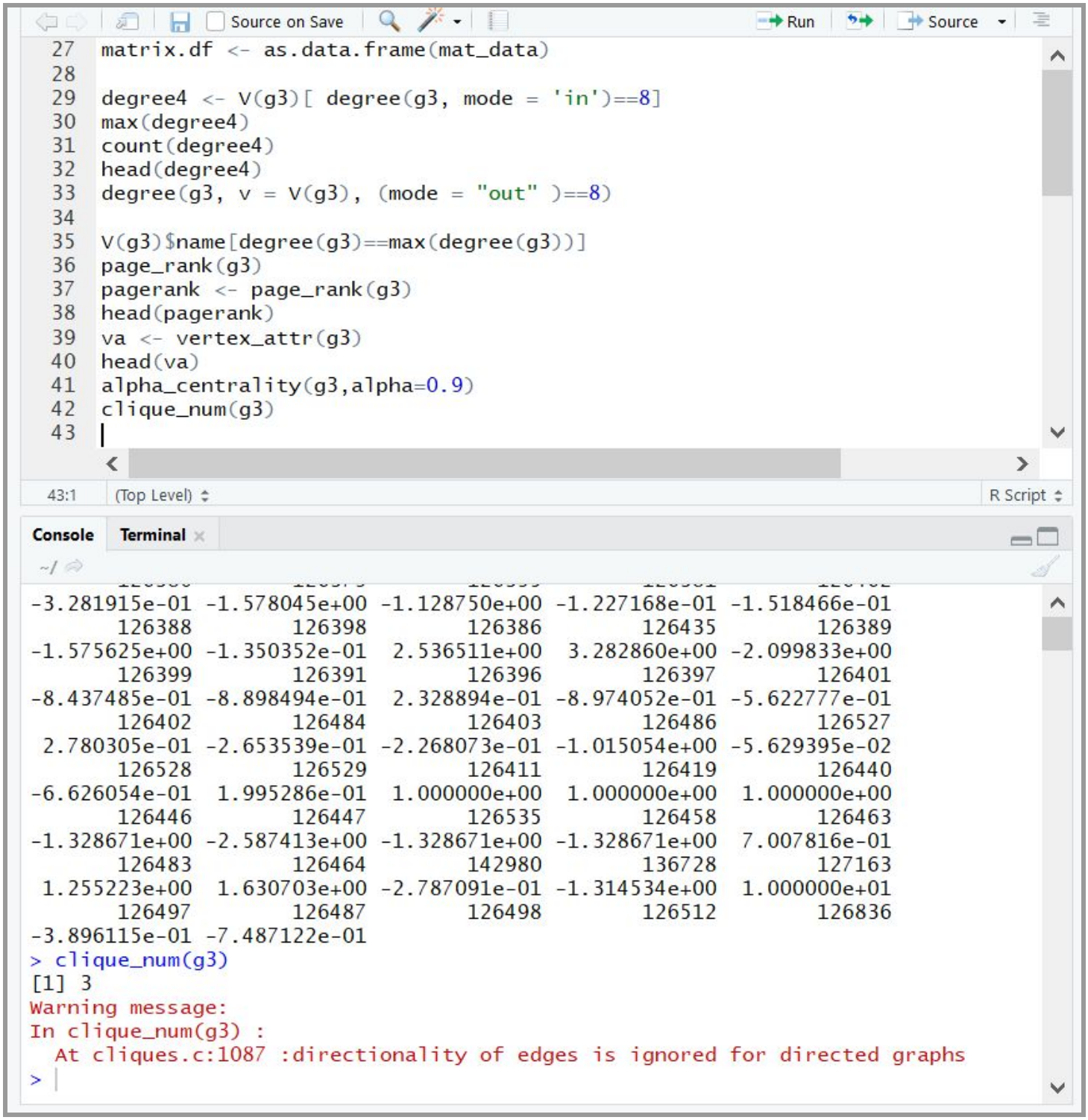
diameter(g3,directed=TRUE,weights=NA)
get_diameter(g3,directed=TRUE,weights=NA)

After using the get_diameter function, we can see that there are multiple longest paths.

```
> diameter(g3, directed=TRUE, weights=NA)
[1] 416
> get_diameter(g3, directed=TRUE, weights=NA)
+ 417/290934 vertices, named, from 4653a36:
  [1] 515136 515137 515138 515124 515119 514997 534895 534503 534502 514966
 [11] 514965 534892 514991 534890 534889 534855 532317 514940 534853 514915
 [21] 506303 505950 534849 505959 534874 534873 534840 534876 505933 505932
 [31] 534870 505902 505901 534857 505997 505170 505008 505009 505011 505167
 [41] 505179 505178 505184 505182 505186 505185 505730 505743 505744 505751
 [51] 505752 505749 505754 505717 505701 505719 505820 505714 505711 505707
 [61] 505692 504695 504696 505685 505682 505680 505649 505644 505642 505639
 [71] 505636 505634 505091 504596 504594 504132 504128 504126 504119 504114
 [81] 504113 504103 504092 504086 504071 504070 504066 504055 503991 503990
 [91] 504046 504049 504054 504063 504067 503964 503959 503881 503880 503994
+ ... omitted several vertices
```

c. Are there multiple cliques?
Yes, there are multiple cliques in the graph that are highest.

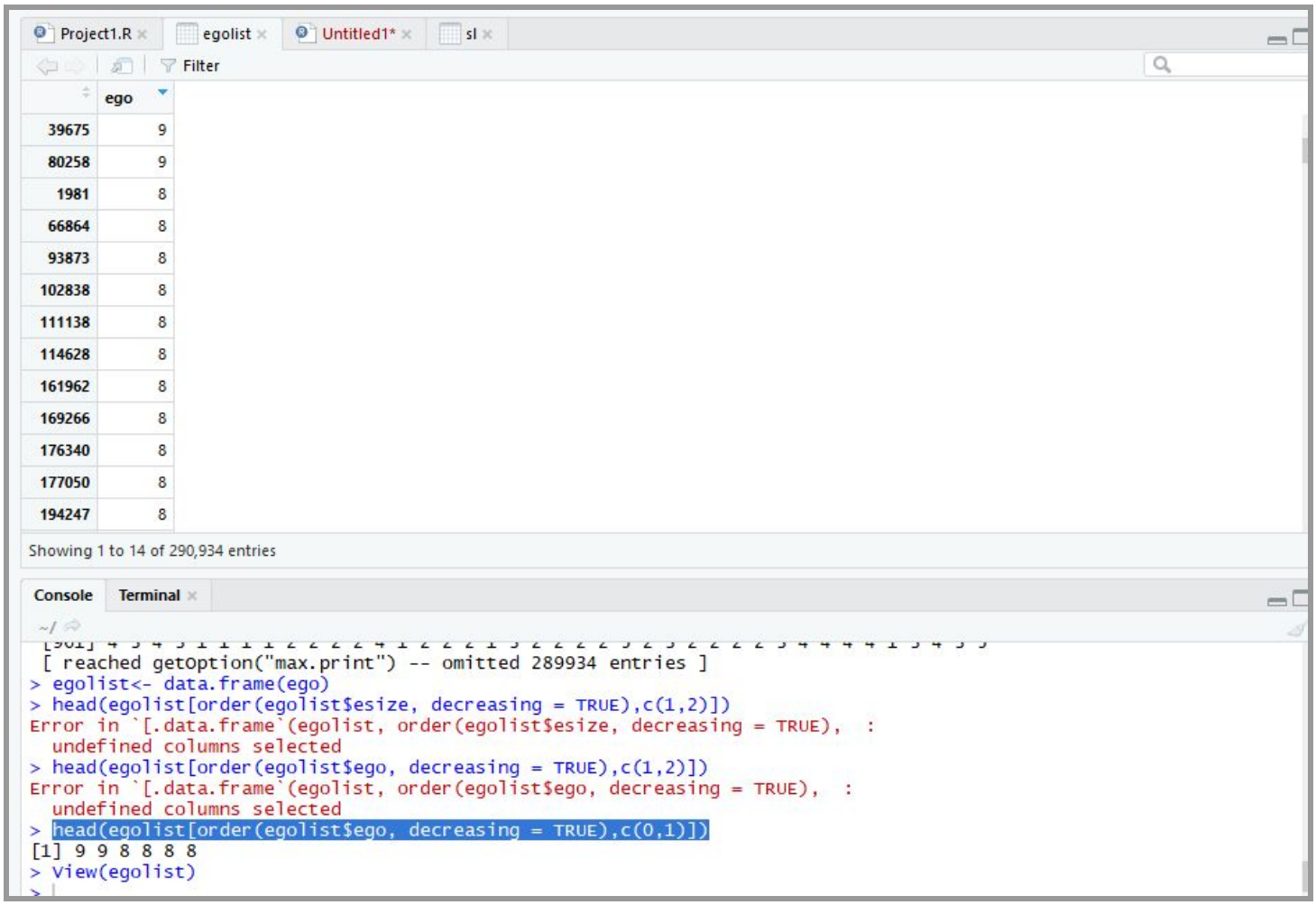
The function clique_num( ) returns the value 3 which indicates that there are 3 largest cliques in the graph


Source on Save
Run
Source
matrix.df <- as.data.frame(mat_data)
degree4 <- V(g3)[degree(g3, mode = 'in')==8]
max(degree4)
count(degree4)
head(degree4)
degree(g3, v = V(g3), (mode = "out")==8)
V(g3)$name[degree(g3)==max(degree(g3))]
page_rank(g3)
pagerank <- page_rank(g3)
head(pagerank)
va <- vertex_attr(g3)
head(va)
alpha_centrality(g3,alpha=0.9)
clique_num(g3)
43:1
(Top Level)
R Script
Console
Terminal
-3.281915e-01 -1.578045e+00 -1.128750e+00 -1.227168e-01 -1.518466e-01
126388 126398 126386 126435 126389
-1.575625e+00 -1.350352e-01 2.536511e+00 3.282860e+00 -2.099833e+00
126399 126391 126396 126397 126401
-8.437485e-01 -8.898494e-01 2.328894e-01 -8.974052e-01 -5.622777e-01
126402 126484 126403 126486 126527
2.780305e-01 -2.653539e-01 -2.268073e-01 -1.015054e+00 -5.629395e-02
126528 126529 126411 126419 126440
-6.626054e-01 1.995286e-01 1.000000e+00 1.000000e+00 1.000000e+00
126446 126447 126535 126458 126463
-1.328671e+00 -2.587413e+00 -1.328671e+00 -1.328671e+00 7.007816e-01
126483 126464 142980 136728 127163
1.255223e+00 1.630703e+00 -2.787091e-01 -1.314534e+00 1.000000e+01
126497 126487 126498 126512 126836
-3.896115e-01 -7.487122e-01
> clique_num(g3)
[1] 3
Warning message:
In clique_num(g3) :
At cliques.c:1087 :directionality of edges is ignored for directed graphs
>

d. Are there more than one person with the highest ego?
Yes, there are more than one person with the highest ego.
To find this we used

ego<-ego_size(g3, nodes = V(g3), mode = c("all"), mindist = 0) *#find the ego of the graph*
egolist<- data.frame(ego) *#convert the ego(numeric data) to a dataframe to sort descendingly*
head(egolist[order(egolist$ego, decreasing = TRUE),c(0,1)]) *#sort descendingly and print out the top few nodes.*

To the above command, the system returns multiple entries with ego size of 9 which clearly indicates that there are more that one person with the highest ego.



e. What is the difference in betweenness centrality vs. power centrality for the cases you find? Consider comparing the nodes that are members of each set. Are there common nodes?

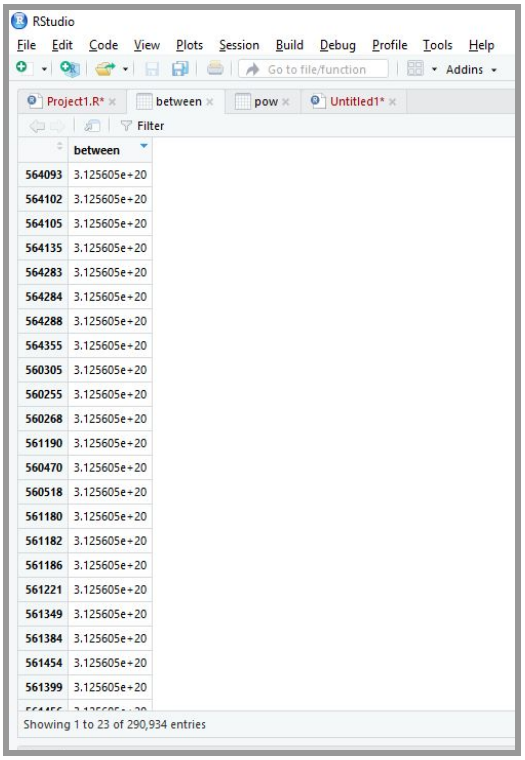
Betweenness centrality: It measures the extent to which a vertex is on paths between other vertices in the graph. Vertices with high betweenness value tend to have considerable influence within a network.

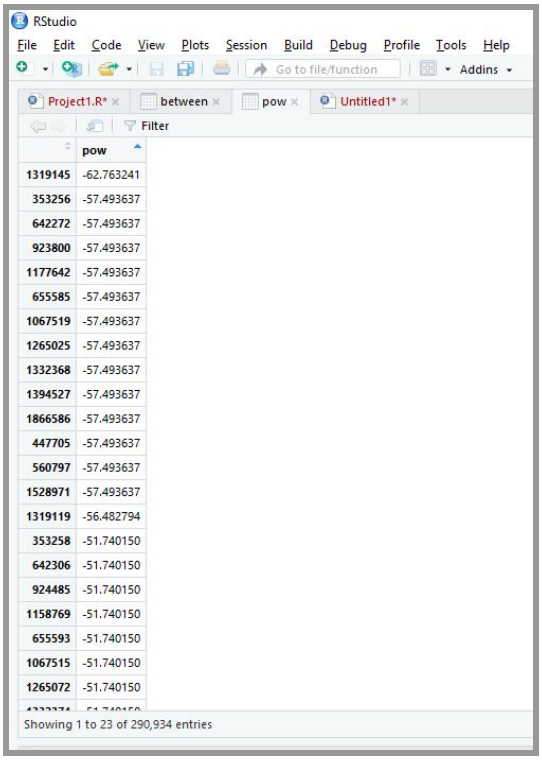
Power Centrality: Also known as '*Bonacich's approach'* to degree centrality is a function of the connections of the vertices in one's neighborhood. The more connections the vertices in the neighborhood have, the more central the vertex is.

between<-betweenness(g3))
between<-data.frame(between)
View(between)

pow<-power_centrality(g3,exponent = 0.9)
View(pow)

Through the results, we can infer that the centralities of both the different methods turn out different. The nodes that seem powerful or the most influential according to the power centrality might not be as influential according to betweenness.





7. Find the 20 nodes with the greatest neighborhood out to a distance 3 from the node. Do any of these neighborhoods overlap?

To get the neighborhood size of each node

```
> #Store the neighbourhood size of each vertex going out to a order of 3
> #g1 is the graph
> #order of the neighbourhood is 3
> #nodes takes all the vertices in graph g1
> #out mode calculate the neighbourhood using only the outgoing edges
> #mindlist = 0, considers minimum distance 0.
> esize <- ego_size(g1, order = 3, nodes = V(g1), mode = c("out"),
+           mindist = 0)
> esize
   [1]  2  2  2  2  3  3  3  1  7  7  8 10  5  5  6  7  5  7  1 13 23 11 17 16  4  1  4
  2  1  1
  [31]  1  6  6 25 25 25 23 24 21 24 23 24 25 17 27 11 17  6  6  6  6  2  2  2  5  5  7
  6  7  9
  [61] 21 21 22 22  1  9  7 11  9 11 10 11  6 10  9  1  2  2  7 10  6  9  3 10 10  9  9
  3  3  4
  [91]  4  4  4 13 12 16 22  8  1  2  2  5  6  8  8  4  4  4  4  5  1  5  1 21 23 22 22
 24 25 21
 [121] 16 22 24 22 23 23 26 16  5 10  9 15 15 13  6 10  4  4  5  6  4  4  4  4  4  1 12
 10 22  1
 [151]  1  4  4  1  4  4  5  4  7 11  2  6  1  2  8  1  4  5  4  4  1  4  6  5  6  5  6
 15 17 17
```

(remaining vertices not displayed)

To get the 20 greatest nodes

```
> #Get the 20 nodes with the highest neighborhood size to order 3 from esize
> b <- order(esize, na.last=TRUE, decreasing=TRUE)[1:20]
> b
 [1]  80258 229484  80137  89901 195437 195453 229944  80140  80256   2336   2370   4491
6  80215
[14]  83196  85707 195426 229634 229938   1686   2328
```

Display the neighborhood size of the 20 greatest nodes

```
> #Display the neighborhood size of nodes in b
> ego_size(g1, order = 3, nodes = b, mode = c("out"),
+                  mindist = 0)
 [1] 40 37 35 34 34 34 34 33 33 32 32 32 32 32 32 32 32 31 31
```

To check overlap:

```
l <- list(as.list(unlist(elist[1])),as.list(unlist(elist[2])),as.list(unlist(elist[3])),
        as.list(unlist(elist[4])),as.list(unlist(elist[5])),as.list(unlist(elist[6])),
        as.list(unlist(elist[7])),as.list(unlist(elist[8])),as.list(unlist(elist[9])),
        as.list(unlist(elist[10])),as.list(unlist(elist[11])),as.list(unlist(elist[12])),
        as.list(unlist(elist[13])),as.list(unlist(elist[14])),as.list(unlist(elist[15])),
        as.list(unlist(elist[16])),as.list(unlist(elist[17])),as.list(unlist(elist[18])),
        as.list(unlist(elist[19])),as.list(unlist(elist[20])))
```

#Get count of common nodes between the 20 greatest nodes
sapply(seq_len(length(l)), function(x)
  sapply(seq_len(length(l)), function(y) length(intersect(unlist(l[x]), unlist(l[y])))))

```
> #Get count of common nodes between the 20 greatest nodes
> sapply(seq_len(length(l)), function(x)
+   sapply(seq_len(length(l)), function(y) length(intersect(unlist(l[x]), unlist(l[y]))
)))
      [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13] [,14]
 [1,]   40    0   29   29    0    0    0   30   30     0     0     0    29     0
 [2,]    0   37    0    0    0    0   26    0    0     0     0     0     0     0
 [3,]   29    0   35   24    0    0    0   24   24     0     0     0    26     0
 [4,]   29    0   24   34    0    0    0   25   25     0     0     0    26     0
 [5,]    0    0    0    0   34   25    0    0    0     0     0     0     0     0
 [6,]    0    0    0    0   25   34    0    0    0     0     0     0     0     0
 [7,]    0   26    0    0    0    0   34    0    0     0     0     0     0     0
 [8,]   30    0   24   25    0    0    0   33   31     0     0     0    24     0
 [9,]   30    0   24   25    0    0    0   31   33     0     0     0    24     0
[10,]    0    0    0    0    0    0    0    0    0    32    25     0     0     0
[11,]    0    0    0    0    0    0    0    0    0    25    32     0     0     0
[12,]    0    0    0    0    0    0    0    0    0     0     0    32     0     0
[13,]   29    0   26   26    0    0    0   24   24     0     0     0    32     0
[14,]    0    0    0    0    0    0    0    0    0     0     0     0     0    32
[15,]    0    0    0    0    0    0    0    0    0     0     0     0     0     0
[16,]    0    0    0    0   26   20    0    0    0     0     0     0     0     0
[17,]    0    4    0    0    0    0    8    0    0     0     0     0     0     0
[18,]    0   17    0    0    0    0   23    0    0     0     0     0     0     0
[19,]    0    0    0    0    0    0    0    0    0     0     0     0     0     0
[20,]    0    0    0    0    0    0    0    0    0    14    18     0     0     0
      [,15] [,16] [,17] [,18] [,19] [,20]
 [1,]     0     0     0     0     0     0
 [2,]     0     0     4    17     0     0
 [3,]     0     0     0     0     0     0
 [4,]     0     0     0     0     0     0
 [5,]     0    26     0     0     0     0
 [6,]     0    20     0     0     0     0
 [7,]     0     0     8    23     0     0
 [8,]     0     0     0     0     0     0
 [9,]     0     0     0     0     0     0
[10,]     0     0     0     0     0    14
[11,]     0     0     0     0     0    18
```

We can see that there are shared vertices between some of the nodes. Example, there are 29 shared nodes between the 1st and 3rd node.
Since they have common nodes, YES, overlap occurs.

a. Build a matrix of 20 nodes with their reachability to the 3rd level

Subcomponent finds all vertices reachable from a given vertex and all vertices from which a given vertex is reachable in a directed graph.

```
> #Matrix m stores first 20 nodes with reachability 3
> #Matrix n stores the 3 reachable vertices from each of the 20 nodes
> m=matrix()
> n = matrix(0, 20, 3)
> a <- 1
> for (k in 1:320){
+     {
+       if(length(subcomponent(g1, k, mode = c("all", "out", "in")))==3)
+       {
+         x <- ((subcomponent(g1, k, mode = c("all", "out", "in"))))
+         m[a] <- k
+         n[a,1] <- n[a,1] + x[1]
+         n[a,2] <- n[a,2] + x[2]
+         n[a,3] <- n[a,3] + x[3]
+         a <- a+1
+       }
+     }
+   }
>
> m
 [1]   5   6   7  83  88  89 249 250 251 257 272 275 295 296 297 305 306 307 310 320
>
```

b. Determine which of the 20 nodes share common nodes, if any, and, for each common node, list the nodes that share that common node.

20 nodes with reachability 3

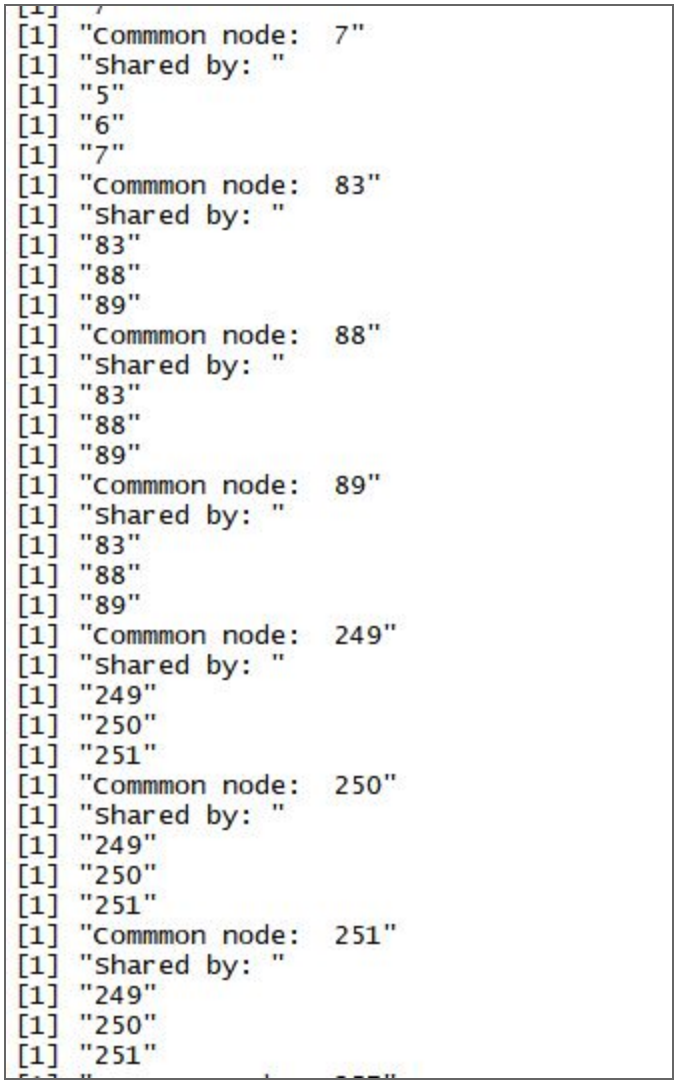
```
> m
 [1]   5   6   7  83  88  89 249 250 251 257 272 275 295 296 297 305 306 307 310 320
```

Reachability matrix of those 20 nodes

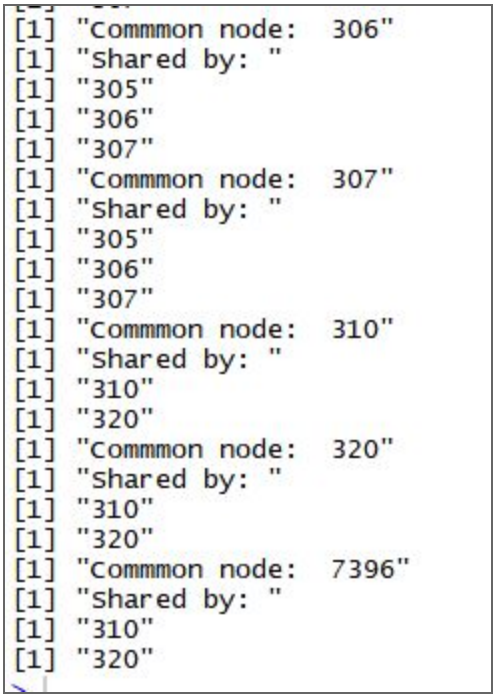
```
> n
    V1  V2   V3
1    5   6    7
2    6   5    7
3    7   5    6
4   83  88   89
5   88  83   89
6   89  83   88
7  249 250  251
8  250 249  251
9  251 249  250
10 257 275  272
11 272 275  257
12 275 257  272
13 295 296  297
14 296 295  297
15 297 295  296
16 305 306  307
17 306 305  307
18 307 305  306
19 310 320 7396
20 320 310 7396
>
```

Getting common nodes and the nodes that share this node:

```
> o=matrix()
> p <-1
>
> for(i in 1:20){
+   for(j in 1:3){
+     if(!(c(n[i,j]) %in% o)){
+     o[p] <- c(n[i,j])
+     p <- p+1
+     #get common nodes and their row numbers
+     if(length(which(apply(n, 1, function(r) any(r %in% c(n[i,j])))))>1)
+     print(paste("Commmon node: ",c(n[i,j])))
+     temp <- which(apply(n, 1, function(r) any(r %in% c(n[i,j]))))
+     print(paste("Shared by: "))
+     for(k in 1:length(which(apply(n, 1, function(r) any(r %in% c(n[i,j]))))))
+     {
+       #get node number from matrix m
+       print(paste(m[temp[k]]))
+     }
+     }
+   }
+ }
[1] "Commmon node:  5"
[1] "Shared by: "
[1] "5"
[1] "6"
[1] "7"
[1] "Commmon node:  6"
[1] "Shared by: "
[1] "5"
[1] "6"
[1] "7"
```


[1] "Commmon node: 7"
[1] "Shared by: "
[1] "5"
[1] "6"
[1] "7"
[1] "Commmon node: 83"
[1] "Shared by: "
[1] "83"
[1] "88"
[1] "89"
[1] "Commmon node: 88"
[1] "Shared by: "
[1] "83"
[1] "88"
[1] "89"
[1] "Commmon node: 89"
[1] "Shared by: "
[1] "83"
[1] "88"
[1] "89"
[1] "Commmon node: 249"
[1] "Shared by: "
[1] "249"
[1] "250"
[1] "251"
[1] "Commmon node: 250"
[1] "Shared by: "
[1] "249"
[1] "250"
[1] "251"
[1] "Commmon node: 251"
[1] "Shared by: "
[1] "249"
[1] "250"
[1] "251"

```
[1] "Commmon node:  257"
[1] "Shared by: "
[1] "257"
[1] "272"
[1] "275"
[1] "Commmon node:  275"
[1] "Shared by: "
[1] "257"
[1] "272"
[1] "275"
[1] "Commmon node:  272"
[1] "Shared by: "
[1] "257"
[1] "272"
[1] "275"
[1] "Commmon node:  295"
[1] "Shared by: "
[1] "295"
[1] "296"
[1] "297"
[1] "Commmon node:  296"
[1] "Shared by: "
[1] "295"
[1] "296"
[1] "297"
[1] "Commmon node:  297"
[1] "Shared by: "
[1] "295"
[1] "296"
[1] "297"
[1] "Commmon node:  305"
[1] "Shared by: "
[1] "305"
[1] "306"
[1] "307"
```



A list of all the functions used in the project:

Functions
is.simple(g3)
is.connected(g3)
eigen_centrality()
edge.disjoint.paths()
page_rank(g3)
vertex_attr(g3)
as_adjacency_matrix(g3)
alpha_centrality(g3,alpha=0.9)
cliques(g3)
rnorm(ecount(g1))
is.directed(g3)
edge_density(g3,loops=TRUE))
neighbors()
ego_size()
mst()

eccentricity()
is.loop(g3)
get_diameter
hub_score
betweenness
mean_distance
which_multiple
are_adjacent
shortest_paths
power_centrality(g3,exponent = 0.9)
head( )
unlist( )
isduplicated( )
subcomponent()
matrix()