ex3

Load the data

```
library(arrow)
```

```
## Warning: package 'arrow' was built under R version 4.1.2
```

```
##
## Attaching package: 'arrow'
```

```
## The following object is masked from 'package:utils':
##
##     timestamp
```

```
df = read_parquet("~/Desktop/McGill/ORGB/2022-ona-assignments/ex3/app_data_sample.parquet")
```

Predicting examiners' gender based on first name:

The gender package attempts to infer gender (or more precisely, sex assigned at birth) based on first names using historical data, typically data that was gathered by the state.

```
library(gender)
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
first_name = df %>%distinct(examiner_name_first)
gender_probability = gender(first_name$examiner_name_first)
gender_dictionary = gender_probability %>% select(name,gender)
df <- df %>% left_join(gender_dictionary, by = c("examiner_name_first" = "name"))
head(df$gender)
```

```
## [1] "female" NA       "female" "female" "male"   "female"
```

The gender package assign gender based on historical data. Some of the name is not in the data set, thus there are some missing gender information. I filled those values by distribution.

```
table(is.na(df$gender))
```

```
##
##   FALSE    TRUE
## 1714618  303859
```

```
gender_na = is.na(df$gender)
gender_fill = sample(df$gender[!gender_na], size = sum(gender_na), replace = TRUE)
df$gender[is.na(df$gender)] <- gender_fill
table(is.na(df$gender))
```

```
##
##   FALSE
## 2018477
```

All the missing value has been filled.

Predicting examiners' race based on last name:

The "predictrace" package predict the race of a surname using U.S. Census data which says how many people of each race has a certain surname.

```
library(predictrace)
race = predict_race(df$examiner_name_last, probability = FALSE)
df$race = race$likely_race
head(df$race,10)
```

```
##  [1] "white" "white" "white" "white" "white" "white" "black" "white" NA
## [10] "asian"
```

Again, fill the missing values based on distribution.

```
table(is.na(df$race))
```

```
##
##   FALSE    TRUE
## 1704131  314346
```

```
race_na = is.na(df$race)
race_fill = sample(df$race[!race_na], size = sum(race_na), replace = TRUE)
df$race[is.na(df$race)] <- race_fill
table(is.na(df$race))
```

```
##
##   FALSE
## 2018477
```

Calculate Tenure

To calculate tenure, I need to calculate the time the application stay in the system.

For most applications, the filing date is the date on which PTO received the application.

The appl_status_date variable indicates the date that the application entered its most recent status (or status as of the end of 2014).

```
tenure_info <- df %>% select(examiner_id, filing_date, appl_status_date)

library(lubridate)
```

```
##
## Attaching package: 'lubridate'

## The following object is masked from 'package:arrow':
##
##     duration

## The following objects are masked from 'package:base':
##
##     date, intersect, setdiff, union
```

```
tenure_info = tenure_info %>% mutate(appl_status_date = as_date(dmy_hms(appl_status_date)))
tenure_info$tenure_days = as.numeric(difftime(tenure_info$appl_status_date,tenure_info$filing_date,units

## detect missing values
table(is.na(tenure_info$tenure_days))
```

```
##
##   FALSE    TRUE
## 2013867    4610
```

```
## fill missing values
tenure_na = is.na(tenure_info$tenure_days)
tenure_fill = sample(tenure_info$tenure_days[!tenure_na], size = sum(tenure_na), replace = TRUE)
tenure_info$tenure_days[is.na(tenure_info$tenure_days)] <- tenure_fill
table(is.na(tenure_info$tenure_days))
```

```
##
##   FALSE
## 2018477
```

```
## join with df
df$tenure = tenure_info$tenure_days
```

Pick two workgroup

The two group I pick is 1648 and 1722. 1600 – Biotechnology 1700 – Chemical and Materials Engineering

```r
wg = as.numeric(substr(df$examiner_art_unit, 1, 3))
df$wg = wg
group_164 = df %>% filter(df$wg == 164)
group_172 = df %>% filter(df$wg == 172)
```

Examing Group 1648

```r
## summary
table(group_164$gender)
```

```
##
## female   male
##  45839  47503
```

```r
table(group_164$race)
```

```
##
## american_indian           asian           black        hispanic           white
##               2           24487            3974            1421           63458
```

Examing Group 1722

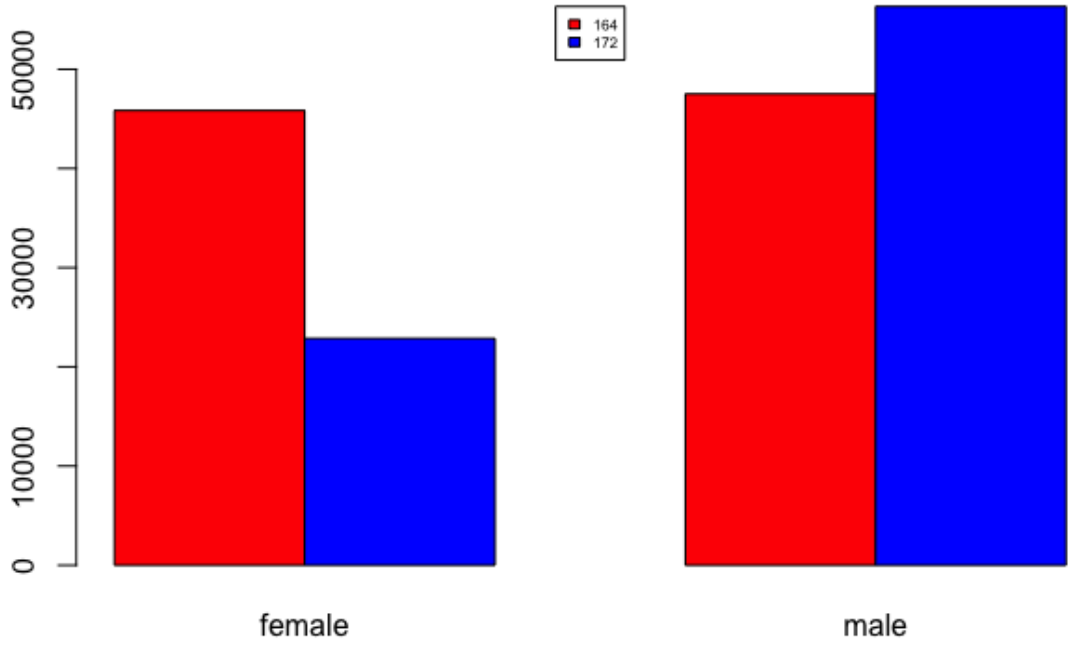
```r
## summary
table(group_172$gender)
```

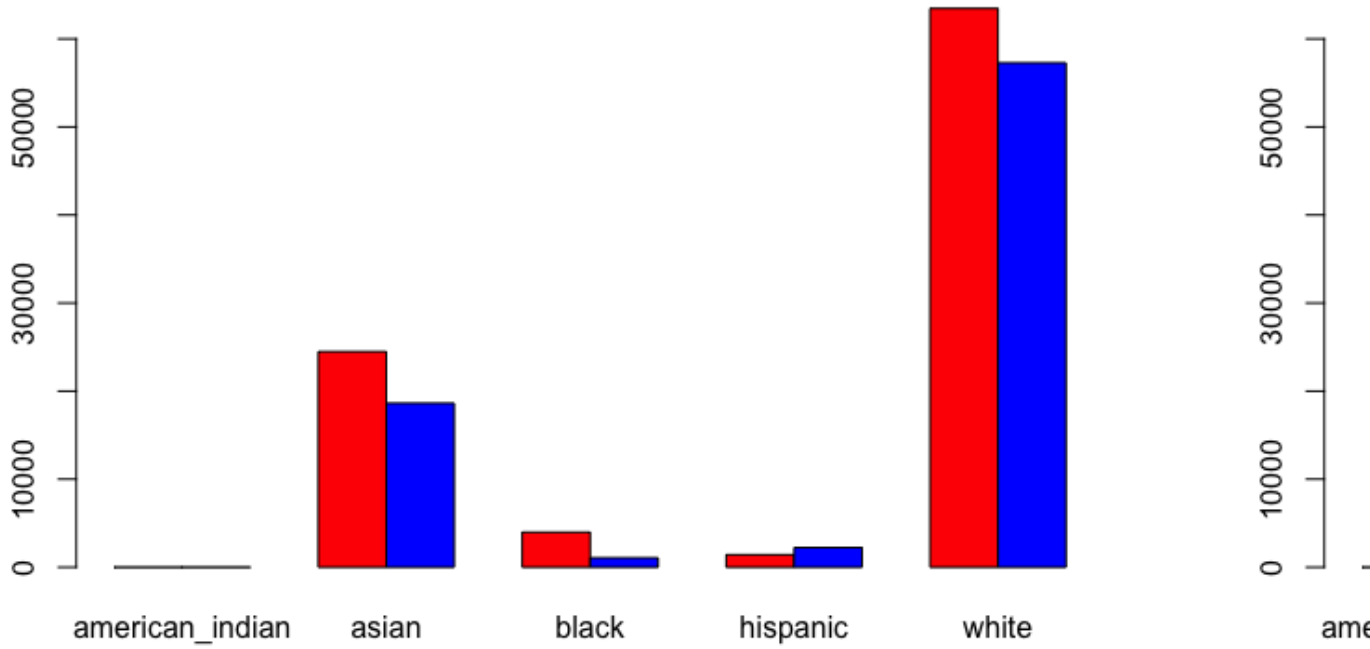
```
##
## female   male
##  22865  56330
```

```r
table(group_172$race)
```

```
##
## american_indian           asian           black        hispanic           white
##               4           18624            1065            2225           57277
```

```r
two_group_gender <- t(cbind(table(group_164$gender), table(group_172$gender)))

barplot(two_group_gender, beside=T, col=c("red","blue"))
par(xpd=T)
legend("top",legend = c("164","172"), fill=c("red","blue"), cex = 0.5)
```


164
172
50000
30000
10000
0
female
male



Create advice networks from edges-sample

```
library(tidyverse)
net = read_csv("~/Desktop/McGill/ORGB/2022-ona-assignments/ex3/edges_sample.csv")

edges_164 = inner_join(df %>% filter(wg == 164),net,by = c("application_number" = "application_number"))

colnames(edges_164) = c("from","to","art_unit")
edges_164 = drop_na(edges_164)

edges_172 = inner_join(df %>% filter(wg == 172),net,by = c("application_number" = "application_number"))

colnames(edges_172) = c("from","to","art_unit")
edges_172 = drop_na(edges_172)
```

Create Nodes

```
edges = rbind(edges_164,edges_172)
node_ego = edges %>% select(from,art_unit) %>%rename(id=from)
node_alter = edges %>% select(to,art_unit)%>%rename(id=to)
nodes_all <-rbind.data.frame(node_ego, node_alter)

nodes = nodes_all %>% distinct(id)
```

```
nodes = nodes %>% mutate(id = as.character(id))
```

Create Graph

```
library(igraph)
```

```
##
## Attaching package: 'igraph'

## The following objects are masked from 'package:purrr':
##
##     compose, simplify

## The following object is masked from 'package:tidyr':
##
##     crossing

## The following object is masked from 'package:tibble':
##
##     as_data_frame

## The following objects are masked from 'package:lubridate':
##
##     %--%, union

## The following objects are masked from 'package:dplyr':
##
##     as_data_frame, groups, union

## The following objects are masked from 'package:stats':
##
##     decompose, spectrum

## The following object is masked from 'package:base':
##
##     union
```

```
net_164 = graph_from_data_frame(d=edges_164, vertices=nodes, directed=TRUE)
net_164
```

```
## IGRAPH abe8745 DN-- 382 1320 --
## + attr: name (v/c), art_unit (e/n)
## + edges from abe8745 (vertex names):
##  [1] 91688->71059 91688->67669 97910->59738 97910->99004 97910->67669
##  [6] 75775->69583 75775->83794 75775->70306 75775->91151 75775->71534
## [11] 70204->72882 70204->94911 71120->65790 59338->72882 61757->65024
## [16] 61757->72882 60067->91747 60067->71087 60067->73722 60067->81365
## [21] 96963->72882 97910->65790 97910->59738 97910->99004 93839->71946
## [26] 74224->65024 74224->94911 96963->67657 87897->69583 87897->72882
## [31] 75775->69583 75775->83794 75775->70306 93839->67669 93839->71946
```

```
## [36] 93839->67669 93839->95981 75775->69583 75775->69583 75775->69583
## + ... omitted several edges
```

```
net_172 = graph_from_data_frame(d=edges_172, vertices=nodes, directed=TRUE)
```

Pick the mesure of centrality

1. Degree centrality is defined as the number of links incident upon a node
2. Eigenvector Centrality is an algorithm that measures the transitive influence of nodes. A high eigenvector score means that a node is connected to many nodes who themselves have high scores.
3. Closeness centrality is a measure of the average shortest distance from each vertex to each other vertex
4. Betweenness centrality is a way of detecting the amount of influence a node has over the flow of information in a graph.

```
## Degree Centrality
V(net_164)$dc <- degree(net_164)
V(net_172)$dc <- degree(net_172)

## Eigenvector Centrality
V(net_164)$ec <- evcent(net_164)$vector
V(net_172)$ec <- evcent(net_172)$vector

## Closeness Centrality
V(net_164)$cc <- closeness(net_164)
V(net_172)$cc <- closeness(net_172)

## Betweenness Centrality
V(net_164)$bc <- betweenness(net_164)
V(net_172)$bc <- betweenness(net_172)
```

Plot the network based on centrality

```
library(ggraph)
library(ggplot2)
library(ggpubr)
# Degree Centrality
dc_164 = ggraph(net_164, layout="kk") +
  geom_edge_link()+
  geom_node_point(aes(size=dc), show.legend=T) + ggtitle("Degree Centrality 164")

# Eigenvector Centrality
ec_164<-ggraph(net_164, layout="kk") +
  geom_edge_link()+
  geom_node_point(aes(size=ec), show.legend=T) + ggtitle("Eigenvector Centrality 164")

# Closeness Centrality
cc_164<-ggraph(net_164, layout="kk") +
  geom_edge_link()+
  geom_node_point(aes(size=cc), show.legend=T) + ggtitle("Closeness Centrality 164")
```

```
# Betweenness Centrality
bc_164<-ggraph(net_164, layout="kk") +
  geom_edge_link()+
  geom_node_point(aes(size=bc), show.legend=T) + ggtitle("Betwenness Centrality 164")
```

Centrality Scores

```
centrality_164 <- data.frame(
                            id = V(net_164)$name,
                        degree      = V(net_164)$dc,
                        closeness   = V(net_164)$cc,
                        betweenness = V(net_164)$bc,
                        eigenvector = V(net_164)$ec)
centrality_164
```

```
##        id degree  closeness betweenness  eigenvector
## 1   91688      2 0.50000000   0.0000000 7.440125e-04
## 2   97910    170 0.01098901   0.0000000 1.000000e+00
## 3   75775     74 0.05882353   0.0000000 5.289362e-02
## 4   70204     50 0.14285714   0.0000000 2.087178e-01
## 5   71120      1 1.00000000   0.0000000 7.229780e-04
## 6   59338     17 0.07142857   0.0000000 2.368914e-02
## 7   61757     15 0.12500000   0.0000000 4.667189e-02
## 8   60067     53 0.06250000   0.0000000 2.659651e-01
## 9   96963     25 0.12500000  26.5000000 3.052454e-02
## 10  93839     33 0.14285714   6.0000000 2.323823e-02
## 11  74224     62 0.12500000   0.0000000 2.960134e-02
## 12  87897     96 0.01694915   0.0000000 1.828619e-01
## 13  97706     22 1.00000000   0.0000000 0.000000e+00
## 14  95604     27 0.04347826   7.3000000 3.620639e-02
## 15  68665     14 0.14285714   0.0000000 2.936425e-02
## 16  59211     43 0.07692308  22.0000000 1.486958e-02
## 17  94046     28 0.03846154   0.0000000 1.094606e-02
## 18  98563     21 0.05555556   0.0000000 1.296573e-02
## 19  84944      2 0.50000000   0.0000000 0.000000e+00
## 20  64659     34 0.16666667   0.0000000 2.892049e-01
## 21  75380      3 0.33333333   0.0000000 8.545698e-03
## 22  71195      1 1.00000000   0.0000000 7.229780e-04
## 23  81117     22 0.14285714   0.0000000 3.273904e-03
## 24  96143     13 0.16666667   0.0000000 5.957523e-02
## 25  97543     13 0.12500000   0.0000000 1.508066e-02
## 26  84896      4 0.25000000   0.0000000 9.202491e-03
## 27  75730      8 0.25000000   0.0000000 2.255907e-03
## 28  62583     21 0.20000000   0.0000000 1.511536e-02
## 29  92784     23 0.33333333   0.0000000 5.269872e-03
## 30  75568     44 0.08333333   0.0000000 2.080392e-01
## 31  85865     22 0.50000000   0.0000000 4.173187e-03
## 32  68436      5 0.25000000   0.0000000 8.786725e-04
## 33  61276     21 0.12500000   2.0000000 9.847097e-02
## 34  85987     24 0.12500000   6.0000000 2.070885e-01
## 35  61048      1 1.00000000   0.0000000 7.438540e-04
```

```
## 36  93421     17 0.09090909   0.0000000 5.460819e-02
## 37  72241      7 0.20000000   0.0000000 2.305370e-02
## 38  68922      9 0.14285714   0.0000000 4.583718e-03
## 39  83794     29 0.50000000  16.0000000 3.148191e-02
## 40  63511     13 0.20000000   0.0000000 8.683155e-03
## 41  93869      4 0.16666667   0.0000000 1.535799e-02
## 42  59693      8 0.05263158   0.0000000 2.010957e-03
## 43  79980      2 0.50000000   0.0000000 4.869150e-04
## 44  71259     17 0.14285714   0.0000000 1.169589e-02
## 45  63470      5 0.50000000   0.0000000 1.068662e-03
## 46  64064      4 0.50000000   0.0000000 4.033194e-02
## 47  82047     57 0.04347826   7.6000000 3.348116e-02
## 48  62397     31 0.10000000   0.6666667 1.965911e-01
## 49  90331     11 0.09090909   1.1000000 5.266137e-02
## 50  71414     12 0.20000000   0.0000000 1.801370e-02
## 51  92572      9 0.12500000   5.0000000 2.442997e-02
## 52  61558      2 0.50000000   0.0000000 7.442756e-03
## 53  63394      5 0.04000000   0.0000000 8.039191e-04
## 54  66336      2 0.50000000   0.0000000 4.540176e-05
## 55  96523      5 0.20000000   0.0000000 3.425991e-04
## 56  65654      6 0.14285714   4.0000000 2.454711e-03
## 57  64507      4 1.00000000   2.3333333 2.927285e-02
## 58  59497      6 0.12500000   0.0000000 1.095277e-03
## 59  79495     10 0.14285714   0.0000000 3.255666e-02
## 60  73260     36 0.03030303   0.0000000 3.656860e-02
## 61  62001      1 1.00000000   0.0000000 4.844712e-04
## 62  98076      5 0.33333333   0.0000000 4.055511e-02
## 63  71437      2 1.00000000   0.0000000 6.046637e-04
## 64  64169      4 1.00000000   0.0000000 2.887833e-02
## 65  86115      6 0.25000000   0.0000000 8.494915e-03
## 66  59658      2 0.50000000   0.0000000 0.000000e+00
## 67  96027     10 0.50000000   0.0000000 3.629112e-02
## 68  71858      4 0.25000000   0.0000000 1.207964e-03
## 69  64445      1 1.00000000   0.0000000 1.237095e-03
## 70  73788      3 0.33333333   0.0000000 1.972022e-03
## 71  97772      5 0.33333333   0.0000000 1.763633e-02
## 72  68445      2 0.50000000   0.0000000 7.942560e-03
## 73  80908      3 0.50000000   0.0000000 0.000000e+00
## 74  97072      1 1.00000000   0.0000000 0.000000e+00
## 75  86403      1 1.00000000   0.0000000 0.000000e+00
## 76  84470      4 0.33333333   0.0000000 1.930838e-03
## 77  96576      1 1.00000000   0.0000000 6.705565e-06
## 78  64506      2 0.50000000   0.0000000 8.243366e-03
## 79  96388      3 0.50000000   0.0000000 3.218043e-03
## 80  76749     15 1.00000000   0.0000000 0.000000e+00
## 81  75243      4 0.25000000   0.0000000 0.000000e+00
## 82  90863     11 1.00000000   1.0000000 1.486915e-02
## 83  90219      9 0.33333333   1.5000000 1.114776e-02
## 84  94719      1 1.00000000   0.0000000 1.117014e-04
## 85  88223      1 1.00000000   0.0000000 5.127562e-05
## 86  98470      2 0.50000000   0.0000000 8.456677e-03
## 87  71089      1 1.00000000   0.0000000 7.438540e-04
## 88  74425      4 0.25000000   0.0000000 6.465110e-05
## 89  95634      3 0.08333333   0.0000000 8.122305e-05
```

```
## 90  97818      0        NaN   0.0000000 0.000000e+00
## 91  87125      0        NaN   0.0000000 0.000000e+00
## 92  97456      0        NaN   0.0000000 0.000000e+00
## 93  93968      0        NaN   0.0000000 0.000000e+00
## 94  62152      0        NaN   0.0000000 0.000000e+00
## 95  94782      0        NaN   0.0000000 0.000000e+00
## 96  67034      0        NaN   0.0000000 0.000000e+00
## 97  92108      0        NaN   0.0000000 0.000000e+00
## 98  91190      0        NaN   0.0000000 0.000000e+00
## 99  98469      0        NaN   0.0000000 0.000000e+00
## 100 95891      0        NaN   0.0000000 0.000000e+00
## 101 73898      0        NaN   0.0000000 0.000000e+00
## 102 59550      0        NaN   0.0000000 0.000000e+00
## 103 98855      0        NaN   0.0000000 0.000000e+00
## 104 97755      0        NaN   0.0000000 0.000000e+00
## 105 83034      0        NaN   0.0000000 0.000000e+00
## 106 62659      0        NaN   0.0000000 0.000000e+00
## 107 76580      0        NaN   0.0000000 0.000000e+00
## 108 75530      0        NaN   0.0000000 0.000000e+00
## 109 85323      0        NaN   0.0000000 0.000000e+00
## 110 74334      0        NaN   0.0000000 0.000000e+00
## 111 78715      0        NaN   0.0000000 0.000000e+00
## 112 94466      0        NaN   0.0000000 0.000000e+00
## 113 84267      0        NaN   0.0000000 0.000000e+00
## 114 92476      0        NaN   0.0000000 0.000000e+00
## 115 75367      0        NaN   0.0000000 0.000000e+00
## 116 65121      0        NaN   0.0000000 0.000000e+00
## 117 90290      0        NaN   0.0000000 0.000000e+00
## 118 66251      0        NaN   0.0000000 0.000000e+00
## 119 95010      0        NaN   0.0000000 0.000000e+00
## 120 63714      0        NaN   0.0000000 0.000000e+00
## 121 69581      0        NaN   0.0000000 0.000000e+00
## 122 86985      0        NaN   0.0000000 0.000000e+00
## 123 61517      0        NaN   0.0000000 0.000000e+00
## 124 69680      0        NaN   0.0000000 0.000000e+00
## 125 68719      0        NaN   0.0000000 0.000000e+00
## 126 62413      0        NaN   0.0000000 0.000000e+00
## 127 97083      0        NaN   0.0000000 0.000000e+00
## 128 71059      1        NaN   0.0000000 1.085728e-05
## 129 67669     33        NaN   0.0000000 5.097378e-02
## 130 59738     83        NaN   0.0000000 6.982489e-01
## 131 99004     82        NaN   0.0000000 6.836561e-01
## 132 69583     45        NaN   0.0000000 7.015643e-02
## 133 70306     11        NaN   0.0000000 8.490570e-03
## 134 91151      5        NaN   0.0000000 3.859350e-03
## 135 71534      5        NaN   0.0000000 3.859350e-03
## 136 72882    154        NaN   0.0000000 4.947334e-01
## 137 94911     47        NaN   0.0000000 5.922194e-02
## 138 65790     29        NaN   0.0000000 4.954321e-02
## 139 65024     65        NaN   0.0000000 2.618701e-02
## 140 91747      2        NaN   0.0000000 4.369782e-03
## 141 71087      7        NaN   0.0000000 1.123998e-02
## 142 73722      1        NaN   0.0000000 3.881195e-03
## 143 81365      1        NaN   0.0000000 3.881195e-03
```

```
## 144 71946     30        NaN   0.0000000 7.298222e-02
## 145 67657      2        NaN   0.0000000 8.908816e-04
## 146 95981      2        NaN   0.0000000 8.727535e-04
## 147 75119     22        NaN   0.0000000 0.000000e+00
## 148 70435      6        NaN   0.0000000 3.170132e-03
## 149 96738      3        NaN   0.0000000 1.529330e-02
## 150 64280     27        NaN   0.0000000 2.826566e-03
## 151 92578      3        NaN   0.0000000 1.227017e-03
## 152 99763      1        NaN   0.0000000 1.892073e-04
## 153 66266     61        NaN   0.0000000 8.477388e-02
## 154 68637      1        NaN   0.0000000 0.000000e+00
## 155 97834      1        NaN   0.0000000 0.000000e+00
## 156 85381     24        NaN   0.0000000 2.008683e-03
## 157 72903      3        NaN   0.0000000 2.608122e-03
## 158 99002      1        NaN   0.0000000 1.342908e-04
## 159 81987      3        NaN   0.0000000 1.327300e-04
## 160 99254     11        NaN   0.0000000 7.423058e-02
## 161 60423     11        NaN   0.0000000 7.423058e-02
## 162 67905      9        NaN   0.0000000 2.464362e-02
## 163 64652      9        NaN   0.0000000 2.464362e-02
## 164 83254     26        NaN   0.0000000 7.179617e-03
## 165 87486     18        NaN   0.0000000 7.654516e-03
## 166 88924      2        NaN   0.0000000 6.044032e-03
## 167 72178      2        NaN   0.0000000 6.044032e-03
## 168 72820      6        NaN   0.0000000 1.915633e-03
## 169 67149      1        NaN   0.0000000 3.035890e-03
## 170 61318      2        NaN   0.0000000 4.881891e-04
## 171 94285      1        NaN   0.0000000 1.459288e-02
## 172 63519      5        NaN   0.0000000 1.620961e-02
## 173 92569     16        NaN   0.0000000 2.071777e-02
## 174 65312      4        NaN   0.0000000 6.237938e-05
## 175 78488      1        NaN   0.0000000 1.267122e-04
## 176 90287      1        NaN   0.0000000 3.022016e-03
## 177 81014      1        NaN   0.0000000 3.022016e-03
## 178 63127      9        NaN   0.0000000 4.730153e-03
## 179 97470     13        NaN   0.0000000 5.868037e-03
## 180 99413     10        NaN   0.0000000 4.402277e-03
## 181 95212     10        NaN   0.0000000 4.402277e-03
## 182 67634     10        NaN   0.0000000 4.402277e-03
## 183 72579     10        NaN   0.0000000 4.402277e-03
## 184 82244      1        NaN   0.0000000 4.885864e-04
## 185 69917     27        NaN   0.0000000 1.619306e-01
## 186 88567      2        NaN   0.0000000 2.918575e-02
## 187 65446     28        NaN   0.0000000 6.449131e-02
## 188 71175      1        NaN   0.0000000 3.456927e-04
## 189 67426      1        NaN   0.0000000 3.456927e-04
## 190 63963      1        NaN   0.0000000 3.456927e-04
## 191 85136      2        NaN   0.0000000 3.024984e-03
## 192 72514      2        NaN   0.0000000 3.024984e-03
## 193 66508      2        NaN   0.0000000 3.024984e-03
## 194 70858      4        NaN   0.0000000 3.073559e-03
## 195 67701      3        NaN   0.0000000 3.766911e-05
## 196 63226      1        NaN   0.0000000 7.968905e-04
## 197 71828      1        NaN   0.0000000 3.364198e-04
```

```
## 198 76315      4        NaN   0.0000000 3.513743e-03
## 199 60958      2        NaN   0.0000000 7.878532e-04
## 200 63190      1        NaN   0.0000000 2.668480e-03
## 201 91232      2        NaN   0.0000000 1.536475e-02
## 202 72912     21        NaN   0.0000000 3.319916e-02
## 203 71174      1        NaN   0.0000000 4.285089e-04
## 204 84269      2        NaN   0.0000000 4.339800e-04
## 205 66378      2        NaN   0.0000000 5.345844e-04
## 206 66565      2        NaN   0.0000000 5.345844e-04
## 207 97329      2        NaN   0.0000000 5.345844e-04
## 208 70201      1        NaN   0.0000000 1.239652e-04
## 209 60487      2        NaN   0.0000000 7.762391e-03
## 210 74382      1        NaN   0.0000000 3.881195e-03
## 211 96339      6        NaN   0.0000000 3.790662e-03
## 212 72158      1        NaN   0.0000000 2.169900e-04
## 213 80106      5        NaN   0.0000000 3.856172e-03
## 214 90742      1        NaN   0.0000000 2.169900e-04
## 215 95085      1        NaN   0.0000000 0.000000e+00
## 216 62142      1        NaN   0.0000000 0.000000e+00
## 217 96865      5        NaN   0.0000000 2.647959e-03
## 218 59803      2        NaN   0.0000000 1.607651e-03
## 219 82997      1        NaN   0.0000000 6.688963e-05
## 220 88294      1        NaN   0.0000000 4.319686e-04
## 221 76280      1        NaN   0.0000000 1.239652e-04
## 222 62823      1        NaN   0.0000000 5.336410e-04
## 223 70907      1        NaN   0.0000000 0.000000e+00
## 224 72352      2        NaN   0.0000000 0.000000e+00
## 225 61013      1        NaN   0.0000000 4.285089e-04
## 226 95478      1        NaN   0.0000000 3.292017e-05
## 227 91016      1        NaN   0.0000000 3.456927e-04
## 228 97402      1        NaN   0.0000000 4.777568e-05
## 229 62947      2        NaN   0.0000000 1.296836e-03
## 230 67013      2        NaN   0.0000000 0.000000e+00
## 231 95784      1        NaN   0.0000000 3.035890e-03
## 232 85761      2        NaN   0.0000000 3.196648e-05
## 233 60045      3        NaN   0.0000000 4.377863e-02
## 234 70164      1        NaN   0.0000000 1.459288e-02
## 235 95084      3        NaN   0.0000000 4.377863e-02
## 236 95494      1        NaN   0.0000000 6.688963e-05
## 237 70079      1        NaN   0.0000000 6.688963e-05
## 238 90154      2        NaN   0.0000000 4.401405e-04
## 239 75394      2        NaN   0.0000000 7.762391e-03
## 240 62411      1        NaN   0.0000000 2.817648e-05
## 241 95223      2        NaN   0.0000000 4.595095e-04
## 242 61105      1        NaN   0.0000000 1.459288e-02
## 243 65131      1        NaN   0.0000000 1.459288e-02
## 244 70142      1        NaN   0.0000000 1.459288e-02
## 245 72355      1        NaN   0.0000000 4.319686e-04
## 246 72814      3        NaN   0.0000000 1.564959e-02
## 247 77761      2        NaN   0.0000000 8.908816e-04
## 248 67435      5        NaN   0.0000000 0.000000e+00
## 249 98700      2        NaN   0.0000000 3.413534e-04
## 250 67138      1        NaN   0.0000000 2.668480e-03
## 251 65737      1        NaN   0.0000000 1.762766e-05
```

```
## 252 93990      1        NaN   0.0000000 1.762766e-05
## 253 94153      1        NaN   0.0000000 0.000000e+00
## 254 93982      1        NaN   0.0000000 0.000000e+00
## 255 98518      1        NaN   0.0000000 0.000000e+00
## 256 64331      1        NaN   0.0000000 0.000000e+00
## 257 80823      1        NaN   0.0000000 2.668480e-03
## 258 88668      1        NaN   0.0000000 7.718700e-04
## 259 66225      1        NaN   0.0000000 2.668480e-03
## 260 60791      1        NaN   0.0000000 2.668480e-03
## 261 59908      1        NaN   0.0000000 2.668480e-03
## 262 76423      1        NaN   0.0000000 2.668480e-03
## 263 94770      1        NaN   0.0000000 2.668480e-03
## 264 76309      1        NaN   0.0000000 2.668480e-03
## 265 91849      1        NaN   0.0000000 2.668480e-03
## 266 69467      1        NaN   0.0000000 2.668480e-03
## 267 70892      1        NaN   0.0000000 2.668480e-03
## 268 97332      1        NaN   0.0000000 2.668480e-03
## 269 90288      1        NaN   0.0000000 2.668480e-03
## 270 86743      1        NaN   0.0000000 2.668480e-03
## 271 61388      1        NaN   0.0000000 2.668480e-03
## 272 95253      1        NaN   0.0000000 2.668480e-03
## 273 68813      1        NaN   0.0000000 2.668480e-03
## 274 97610      1        NaN   0.0000000 2.668480e-03
## 275 93800      1        NaN   0.0000000 2.668480e-03
## 276 94355      1        NaN   0.0000000 2.668480e-03
## 277 80910      1        NaN   0.0000000 2.668480e-03
## 278 60266      1        NaN   0.0000000 2.668480e-03
## 279 71528      1        NaN   0.0000000 2.668480e-03
## 280 59868      1        NaN   0.0000000 2.668480e-03
## 281 79106      1        NaN   0.0000000 2.668480e-03
## 282 64004      1        NaN   0.0000000 1.459288e-02
## 283 66448      1        NaN   0.0000000 2.668480e-03
## 284 93578      1        NaN   0.0000000 5.336410e-04
## 285 68916      1        NaN   0.0000000 5.336410e-04
## 286 99524      1        NaN   0.0000000 5.336410e-04
## 287 94123      1        NaN   0.0000000 5.336410e-04
## 288 88661      1        NaN   0.0000000 5.336410e-04
## 289 65304      1        NaN   0.0000000 5.336410e-04
## 290 89412      1        NaN   0.0000000 5.336410e-04
## 291 65541      1        NaN   0.0000000 5.336410e-04
## 292 75560      1        NaN   0.0000000 5.336410e-04
## 293 92268      1        NaN   0.0000000 2.668480e-03
## 294 63694      1        NaN   0.0000000 2.668480e-03
## 295 59258      1        NaN   0.0000000 2.668480e-03
## 296 99480      1        NaN   0.0000000 2.668480e-03
## 297 68265      1        NaN   0.0000000 2.668480e-03
## 298 62591      1        NaN   0.0000000 2.668480e-03
## 299 64355      2        NaN   0.0000000 2.295674e-04
## 300 98182      1        NaN   0.0000000 4.285089e-04
## 301 94915      1        NaN   0.0000000 4.750952e-04
## 302 95525      1        NaN   0.0000000 4.750952e-04
## 303 92706      1        NaN   0.0000000 2.668480e-03
## 304 94847      1        NaN   0.0000000 2.668480e-03
## 305 67620      1        NaN   0.0000000 2.668480e-03
```

```
## 306 99892      1        NaN   0.0000000 2.668480e-03
## 307 77063      2        NaN   0.0000000 1.056711e-03
## 308 61925      1        NaN   0.0000000 1.459288e-02
## 309 68977      1        NaN   0.0000000 1.459288e-02
## 310 73239      1        NaN   0.0000000 5.283554e-04
## 311 75932      1        NaN   0.0000000 2.628716e-04
## 312 69378      0        NaN   0.0000000 0.000000e+00
## 313 77915      0        NaN   0.0000000 0.000000e+00
## 314 61863      0        NaN   0.0000000 0.000000e+00
## 315 95344      0        NaN   0.0000000 0.000000e+00
## 316 78379      0        NaN   0.0000000 0.000000e+00
## 317 92991      0        NaN   0.0000000 0.000000e+00
## 318 62499      0        NaN   0.0000000 0.000000e+00
## 319 65621      0        NaN   0.0000000 0.000000e+00
## 320 75933      0        NaN   0.0000000 0.000000e+00
## 321 98489      0        NaN   0.0000000 0.000000e+00
## 322 60203      0        NaN   0.0000000 0.000000e+00
## 323 67829      0        NaN   0.0000000 0.000000e+00
## 324 60851      0        NaN   0.0000000 0.000000e+00
## 325 74052      0        NaN   0.0000000 0.000000e+00
## 326 98826      0        NaN   0.0000000 0.000000e+00
## 327 65934      0        NaN   0.0000000 0.000000e+00
## 328 97338      0        NaN   0.0000000 0.000000e+00
## 329 99489      0        NaN   0.0000000 0.000000e+00
## 330 95299      0        NaN   0.0000000 0.000000e+00
## 331 96697      0        NaN   0.0000000 0.000000e+00
## 332 69099      0        NaN   0.0000000 0.000000e+00
## 333 98852      0        NaN   0.0000000 0.000000e+00
## 334 90995      0        NaN   0.0000000 0.000000e+00
## 335 70248      0        NaN   0.0000000 0.000000e+00
## 336 77651      0        NaN   0.0000000 0.000000e+00
## 337 77184      0        NaN   0.0000000 0.000000e+00
## 338 97312      0        NaN   0.0000000 0.000000e+00
## 339 72666      0        NaN   0.0000000 0.000000e+00
## 340 74048      0        NaN   0.0000000 0.000000e+00
## 341 62778      0        NaN   0.0000000 0.000000e+00
## 342 78856      0        NaN   0.0000000 0.000000e+00
## 343 67890      0        NaN   0.0000000 0.000000e+00
## 344 61408      0        NaN   0.0000000 0.000000e+00
## 345 99787      0        NaN   0.0000000 0.000000e+00
## 346 86422      0        NaN   0.0000000 0.000000e+00
## 347 70788      0        NaN   0.0000000 0.000000e+00
## 348 77228      0        NaN   0.0000000 0.000000e+00
## 349 69511      0        NaN   0.0000000 0.000000e+00
## 350 66182      0        NaN   0.0000000 0.000000e+00
## 351 71397      0        NaN   0.0000000 0.000000e+00
## 352 95065      0        NaN   0.0000000 0.000000e+00
## 353 81984      0        NaN   0.0000000 0.000000e+00
## 354 60437      0        NaN   0.0000000 0.000000e+00
## 355 80181      0        NaN   0.0000000 0.000000e+00
## 356 67698      0        NaN   0.0000000 0.000000e+00
## 357 95160      0        NaN   0.0000000 0.000000e+00
## 358 94771      0        NaN   0.0000000 0.000000e+00
## 359 98738      0        NaN   0.0000000 0.000000e+00
```

```
## 360 63372      0        NaN   0.0000000 0.000000e+00
## 361 95432      0        NaN   0.0000000 0.000000e+00
## 362 59269      0        NaN   0.0000000 0.000000e+00
## 363 63482      0        NaN   0.0000000 0.000000e+00
## 364 94860      0        NaN   0.0000000 0.000000e+00
## 365 89466      0        NaN   0.0000000 0.000000e+00
## 366 95666      0        NaN   0.0000000 0.000000e+00
## 367 89404      0        NaN   0.0000000 0.000000e+00
## 368 73564      0        NaN   0.0000000 0.000000e+00
## 369 64184      0        NaN   0.0000000 0.000000e+00
## 370 67547      0        NaN   0.0000000 0.000000e+00
## 371 67514      0        NaN   0.0000000 0.000000e+00
## 372 97267      0        NaN   0.0000000 0.000000e+00
## 373 64350      0        NaN   0.0000000 0.000000e+00
## 374 99577      0        NaN   0.0000000 0.000000e+00
## 375 91123      0        NaN   0.0000000 0.000000e+00
## 376 88204      0        NaN   0.0000000 0.000000e+00
## 377 97922      0        NaN   0.0000000 0.000000e+00
## 378 94768      0        NaN   0.0000000 0.000000e+00
## 379 81287      0        NaN   0.0000000 0.000000e+00
## 380 66203      0        NaN   0.0000000 0.000000e+00
## 381 82412      0        NaN   0.0000000 0.000000e+00
## 382 62098      0        NaN   0.0000000 0.000000e+00
```

```
centrality_172 <- data.frame(id = V(net_164)$name,
                         degree      = V(net_172)$dc,
                         closeness   = V(net_172)$cc,
                         betweenness = V(net_172)$bc,
                         eigenvector = V(net_172)$ec)
centrality_172
```

```
##        id degree  closeness betweenness  eigenvector
## 1   91688      0        NaN           0 4.356715e-17
## 2   97910      0        NaN           0 4.356715e-17
## 3   75775      0        NaN           0 4.356715e-17
## 4   70204      0        NaN           0 4.356715e-17
## 5   71120      0        NaN           0 4.356715e-17
## 6   59338      0        NaN           0 4.356715e-17
## 7   61757      0        NaN           0 4.356715e-17
## 8   60067      0        NaN           0 4.356715e-17
## 9   96963      0        NaN           0 4.356715e-17
## 10  93839      0        NaN           0 4.356715e-17
## 11  74224      0        NaN           0 4.356715e-17
## 12  87897      0        NaN           0 4.356715e-17
## 13  97706      0        NaN           0 4.356715e-17
## 14  95604      0        NaN           0 4.356715e-17
## 15  68665      0        NaN           0 4.356715e-17
## 16  59211      0        NaN           0 4.356715e-17
## 17  94046      0        NaN           0 4.356715e-17
## 18  98563      0        NaN           0 4.356715e-17
## 19  84944      0        NaN           0 4.356715e-17
## 20  64659      0        NaN           0 4.356715e-17
## 21  75380      0        NaN           0 4.356715e-17
## 22  71195      0        NaN           0 4.356715e-17
```

```
## 23  81117      0        NaN          0 4.356715e-17
## 24  96143      0        NaN          0 4.356715e-17
## 25  97543      0        NaN          0 4.356715e-17
## 26  84896      0        NaN          0 4.356715e-17
## 27  75730      0        NaN          0 4.356715e-17
## 28  62583      0        NaN          0 4.356715e-17
## 29  92784      0        NaN          0 4.356715e-17
## 30  75568      0        NaN          0 4.356715e-17
## 31  85865      0        NaN          0 4.356715e-17
## 32  68436      0        NaN          0 4.356715e-17
## 33  61276      0        NaN          0 4.356715e-17
## 34  85987      0        NaN          0 4.356715e-17
## 35  61048      0        NaN          0 4.356715e-17
## 36  93421      0        NaN          0 4.356715e-17
## 37  72241      0        NaN          0 4.356715e-17
## 38  68922      0        NaN          0 4.356715e-17
## 39  83794      0        NaN          0 4.356715e-17
## 40  63511      0        NaN          0 4.356715e-17
## 41  93869      0        NaN          0 4.356715e-17
## 42  59693      0        NaN          0 4.356715e-17
## 43  79980      0        NaN          0 4.356715e-17
## 44  71259      0        NaN          0 4.356715e-17
## 45  63470      0        NaN          0 4.356715e-17
## 46  64064      0        NaN          0 4.356715e-17
## 47  82047      0        NaN          0 4.356715e-17
## 48  62397      0        NaN          0 4.356715e-17
## 49  90331      0        NaN          0 4.356715e-17
## 50  71414      0        NaN          0 4.356715e-17
## 51  92572      0        NaN          0 4.356715e-17
## 52  61558      0        NaN          0 4.356715e-17
## 53  63394      0        NaN          0 4.356715e-17
## 54  66336      0        NaN          0 4.356715e-17
## 55  96523      0        NaN          0 4.356715e-17
## 56  65654      0        NaN          0 4.356715e-17
## 57  64507      0        NaN          0 4.356715e-17
## 58  59497      0        NaN          0 4.356715e-17
## 59  79495      0        NaN          0 4.356715e-17
## 60  73260      0        NaN          0 4.356715e-17
## 61  62001      0        NaN          0 4.356715e-17
## 62  98076      0        NaN          0 4.356715e-17
## 63  71437      0        NaN          0 4.356715e-17
## 64  64169      0        NaN          0 4.356715e-17
## 65  86115      0        NaN          0 4.356715e-17
## 66  59658      0        NaN          0 4.356715e-17
## 67  96027      0        NaN          0 4.356715e-17
## 68  71858      0        NaN          0 4.356715e-17
## 69  64445      0        NaN          0 4.356715e-17
## 70  73788      0        NaN          0 4.356715e-17
## 71  97772      0        NaN          0 4.356715e-17
## 72  68445      0        NaN          0 4.356715e-17
## 73  80908      0        NaN          0 4.356715e-17
## 74  97072      0        NaN          0 4.356715e-17
## 75  86403      0        NaN          0 4.356715e-17
## 76  84470      0        NaN          0 4.356715e-17
```

```
## 77  96576      0        NaN           0 4.356715e-17
## 78  64506      0        NaN           0 4.356715e-17
## 79  96388      0        NaN           0 4.356715e-17
## 80  76749      0        NaN           0 4.356715e-17
## 81  75243      0        NaN           0 4.356715e-17
## 82  90863      0        NaN           0 4.356715e-17
## 83  90219      0        NaN           0 4.356715e-17
## 84  94719      0        NaN           0 4.356715e-17
## 85  88223      0        NaN           0 4.356715e-17
## 86  98470      0        NaN           0 4.356715e-17
## 87  71089      0        NaN           0 4.356715e-17
## 88  74425      0        NaN           0 4.356715e-17
## 89  95634      0        NaN           0 4.356715e-17
## 90  97818      7 0.16666667           0 1.603375e-02
## 91  87125      8 0.33333333          12 6.224787e-02
## 92  97456      4 0.50000000           0 1.955749e-06
## 93  93968     11 0.33333333           0 9.513752e-04
## 94  62152     12 0.16666667           0 3.004243e-02
## 95  94782     19 0.33333333           2 1.359346e-03
## 96  67034     31 0.07142857           0 1.000000e+00
## 97  92108      1 1.00000000           0 2.287811e-04
## 98  91190      6        NaN           0 1.753895e-17
## 99  98469      3 0.33333333           0 1.150516e-16
## 100 95891     12 0.25000000           0 7.014774e-05
## 101 73898      4 0.25000000           0 1.515138e-16
## 102 59550      6 0.25000000           0 4.649829e-04
## 103 98855      2 0.16666667           0 1.328568e-04
## 104 97755      1 1.00000000           0 5.318553e-05
## 105 83034      6 0.05555556           0 1.482297e-02
## 106 62659     11 0.11111111           5 7.788714e-03
## 107 76580      1 1.00000000           0 6.496768e-07
## 108 75530      1 1.00000000           0 3.519392e-17
## 109 85323      3 0.50000000           0 5.107478e-04
## 110 74334      1 0.20000000           0 2.407413e-17
## 111 78715      4 0.50000000           0 4.231461e-05
## 112 94466      1 1.00000000           0 2.287811e-04
## 113 84267      3 0.33333333           0 1.105879e-16
## 114 92476      1 1.00000000           0 3.556291e-17
## 115 75367      3 0.50000000           2 1.149087e-16
## 116 65121      1 1.00000000           0 3.722526e-17
## 117 90290      1 1.00000000           0 4.096747e-03
## 118 66251      6 0.16666667           0 2.248197e-16
## 119 95010      5 0.33333333           0 1.392886e-01
## 120 63714      2 0.50000000           0 6.767847e-17
## 121 69581      2 0.50000000           0 4.125087e-03
## 122 86985      2 0.50000000           0 4.125087e-03
## 123 61517      1 1.00000000           0 3.824385e-17
## 124 69680      3 0.11111111           0 1.064280e-02
## 125 68719     15 0.06666667           0 6.341172e-16
## 126 62413      1 1.00000000           0 3.917222e-17
## 127 97083      6 0.16666667           0 2.315594e-16
## 128 71059      0        NaN           0 4.356715e-17
## 129 67669      0        NaN           0 4.356715e-17
## 130 59738      0        NaN           0 4.356715e-17
```

```
## 131 99004      0        NaN          0 4.356715e-17
## 132 69583      0        NaN          0 4.356715e-17
## 133 70306      0        NaN          0 4.356715e-17
## 134 91151      0        NaN          0 4.356715e-17
## 135 71534      0        NaN          0 4.356715e-17
## 136 72882      0        NaN          0 4.356715e-17
## 137 94911      0        NaN          0 4.356715e-17
## 138 65790      0        NaN          0 4.356715e-17
## 139 65024      0        NaN          0 4.356715e-17
## 140 91747      0        NaN          0 4.356715e-17
## 141 71087      0        NaN          0 4.356715e-17
## 142 73722      0        NaN          0 4.356715e-17
## 143 81365      0        NaN          0 4.356715e-17
## 144 71946      0        NaN          0 4.356715e-17
## 145 67657      0        NaN          0 4.356715e-17
## 146 95981      0        NaN          0 4.356715e-17
## 147 75119      0        NaN          0 4.356715e-17
## 148 70435      0        NaN          0 4.356715e-17
## 149 96738      0        NaN          0 4.356715e-17
## 150 64280      0        NaN          0 4.356715e-17
## 151 92578      0        NaN          0 4.356715e-17
## 152 99763      0        NaN          0 4.356715e-17
## 153 66266      0        NaN          0 4.356715e-17
## 154 68637      0        NaN          0 4.356715e-17
## 155 97834      0        NaN          0 4.356715e-17
## 156 85381      0        NaN          0 4.356715e-17
## 157 72903      0        NaN          0 4.356715e-17
## 158 99002      0        NaN          0 4.356715e-17
## 159 81987      0        NaN          0 4.356715e-17
## 160 99254      0        NaN          0 4.356715e-17
## 161 60423      0        NaN          0 4.356715e-17
## 162 67905      0        NaN          0 4.356715e-17
## 163 64652      0        NaN          0 4.356715e-17
## 164 83254      0        NaN          0 4.356715e-17
## 165 87486      0        NaN          0 4.356715e-17
## 166 88924      0        NaN          0 4.356715e-17
## 167 72178      0        NaN          0 4.356715e-17
## 168 72820      0        NaN          0 4.356715e-17
## 169 67149      0        NaN          0 4.356715e-17
## 170 61318      0        NaN          0 4.356715e-17
## 171 94285      0        NaN          0 4.356715e-17
## 172 63519      0        NaN          0 4.356715e-17
## 173 92569      8        NaN          0 3.289088e-05
## 174 65312      0        NaN          0 4.356715e-17
## 175 78488      0        NaN          0 4.356715e-17
## 176 90287      0        NaN          0 4.356715e-17
## 177 81014      0        NaN          0 4.356715e-17
## 178 63127      0        NaN          0 4.356715e-17
## 179 97470      0        NaN          0 4.356715e-17
## 180 99413      0        NaN          0 4.356715e-17
## 181 95212      0        NaN          0 4.356715e-17
## 182 67634      0        NaN          0 4.356715e-17
## 183 72579      0        NaN          0 4.356715e-17
## 184 82244      0        NaN          0 4.356715e-17
```

```
## 185 69917      0        NaN          0 4.356715e-17
## 186 88567      0        NaN          0 4.356715e-17
## 187 65446      0        NaN          0 4.356715e-17
## 188 71175      0        NaN          0 4.356715e-17
## 189 67426      0        NaN          0 4.356715e-17
## 190 63963      0        NaN          0 4.356715e-17
## 191 85136      0        NaN          0 4.356715e-17
## 192 72514      0        NaN          0 4.356715e-17
## 193 66508      0        NaN          0 4.356715e-17
## 194 70858      0        NaN          0 4.356715e-17
## 195 67701      0        NaN          0 4.356715e-17
## 196 63226      0        NaN          0 4.356715e-17
## 197 71828      0        NaN          0 4.356715e-17
## 198 76315      0        NaN          0 4.356715e-17
## 199 60958      0        NaN          0 4.356715e-17
## 200 63190      0        NaN          0 4.356715e-17
## 201 91232      0        NaN          0 4.356715e-17
## 202 72912      0        NaN          0 4.356715e-17
## 203 71174      0        NaN          0 4.356715e-17
## 204 84269      0        NaN          0 4.356715e-17
## 205 66378      0        NaN          0 4.356715e-17
## 206 66565      0        NaN          0 4.356715e-17
## 207 97329      0        NaN          0 4.356715e-17
## 208 70201      0        NaN          0 4.356715e-17
## 209 60487      0        NaN          0 4.356715e-17
## 210 74382      0        NaN          0 4.356715e-17
## 211 96339      0        NaN          0 4.356715e-17
## 212 72158      0        NaN          0 4.356715e-17
## 213 80106      0        NaN          0 4.356715e-17
## 214 90742      0        NaN          0 4.356715e-17
## 215 95085      0        NaN          0 4.356715e-17
## 216 62142      0        NaN          0 4.356715e-17
## 217 96865      0        NaN          0 4.356715e-17
## 218 59803      0        NaN          0 4.356715e-17
## 219 82997      0        NaN          0 4.356715e-17
## 220 88294      0        NaN          0 4.356715e-17
## 221 76280      0        NaN          0 4.356715e-17
## 222 62823      0        NaN          0 4.356715e-17
## 223 70907      0        NaN          0 4.356715e-17
## 224 72352      0        NaN          0 4.356715e-17
## 225 61013      0        NaN          0 4.356715e-17
## 226 95478      0        NaN          0 4.356715e-17
## 227 91016      0        NaN          0 4.356715e-17
## 228 97402      0        NaN          0 4.356715e-17
## 229 62947      0        NaN          0 4.356715e-17
## 230 67013      0        NaN          0 4.356715e-17
## 231 95784      0        NaN          0 4.356715e-17
## 232 85761      0        NaN          0 4.356715e-17
## 233 60045      0        NaN          0 4.356715e-17
## 234 70164      0        NaN          0 4.356715e-17
## 235 95084      0        NaN          0 4.356715e-17
## 236 95494      0        NaN          0 4.356715e-17
## 237 70079      0        NaN          0 4.356715e-17
## 238 90154      0        NaN          0 4.356715e-17
```

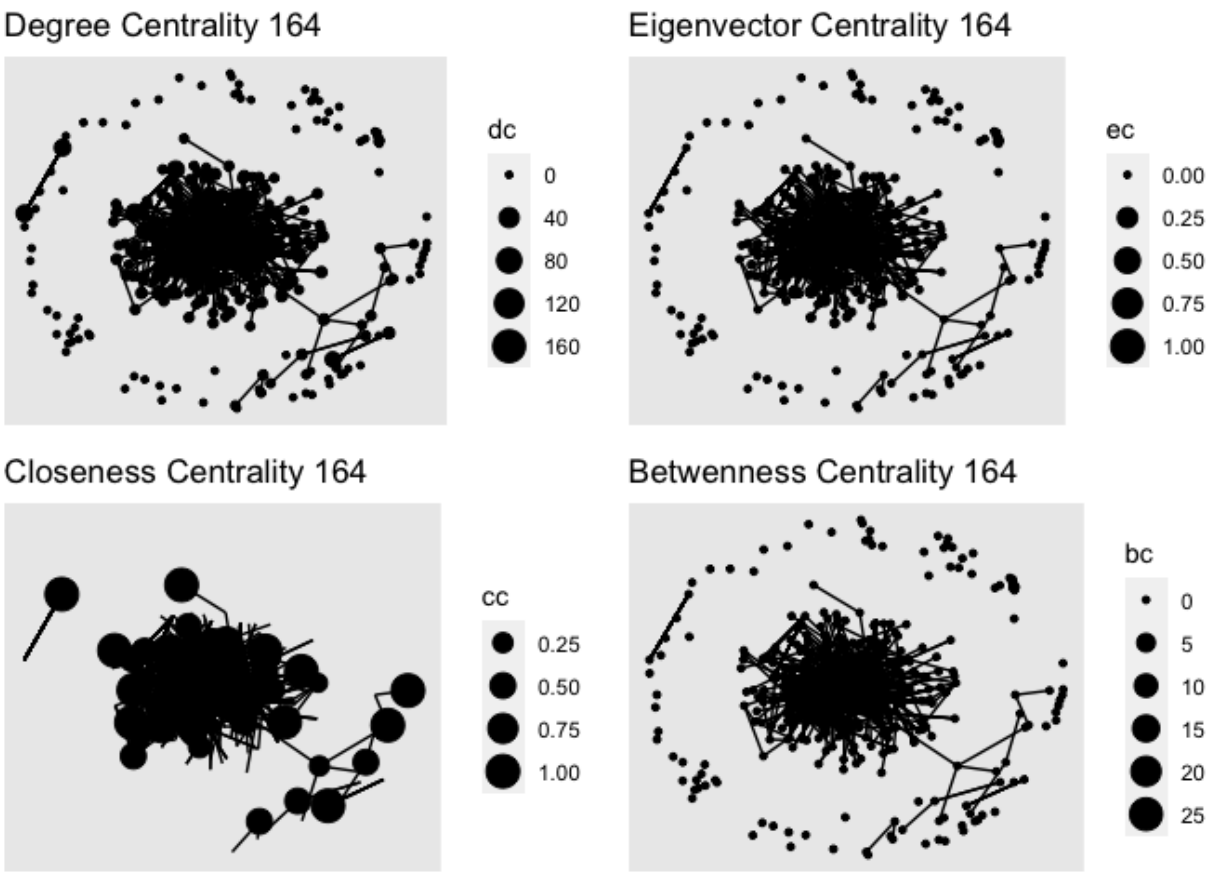
```
## 239 75394      0        NaN          0 4.356715e-17
## 240 62411      0        NaN          0 4.356715e-17
## 241 95223      0        NaN          0 4.356715e-17
## 242 61105      0        NaN          0 4.356715e-17
## 243 65131      0        NaN          0 4.356715e-17
## 244 70142      0        NaN          0 4.356715e-17
## 245 72355      0        NaN          0 4.356715e-17
## 246 72814      0        NaN          0 4.356715e-17
## 247 77761      0        NaN          0 4.356715e-17
## 248 67435      0        NaN          0 4.356715e-17
## 249 98700      0        NaN          0 4.356715e-17
## 250 67138      0        NaN          0 4.356715e-17
## 251 65737      0        NaN          0 4.356715e-17
## 252 93990      0        NaN          0 4.356715e-17
## 253 94153      0        NaN          0 4.356715e-17
## 254 93982      0        NaN          0 4.356715e-17
## 255 98518      0        NaN          0 4.356715e-17
## 256 64331      0        NaN          0 4.356715e-17
## 257 80823      0        NaN          0 4.356715e-17
## 258 88668      0        NaN          0 4.356715e-17
## 259 66225      0        NaN          0 4.356715e-17
## 260 60791      0        NaN          0 4.356715e-17
## 261 59908      0        NaN          0 4.356715e-17
## 262 76423      0        NaN          0 4.356715e-17
## 263 94770      0        NaN          0 4.356715e-17
## 264 76309      0        NaN          0 4.356715e-17
## 265 91849      0        NaN          0 4.356715e-17
## 266 69467      0        NaN          0 4.356715e-17
## 267 70892      0        NaN          0 4.356715e-17
## 268 97332      0        NaN          0 4.356715e-17
## 269 90288      0        NaN          0 4.356715e-17
## 270 86743      0        NaN          0 4.356715e-17
## 271 61388      0        NaN          0 4.356715e-17
## 272 95253      0        NaN          0 4.356715e-17
## 273 68813      0        NaN          0 4.356715e-17
## 274 97610      0        NaN          0 4.356715e-17
## 275 93800      0        NaN          0 4.356715e-17
## 276 94355      0        NaN          0 4.356715e-17
## 277 80910      0        NaN          0 4.356715e-17
## 278 60266      0        NaN          0 4.356715e-17
## 279 71528      0        NaN          0 4.356715e-17
## 280 59868      0        NaN          0 4.356715e-17
## 281 79106      0        NaN          0 4.356715e-17
## 282 64004      0        NaN          0 4.356715e-17
## 283 66448      0        NaN          0 4.356715e-17
## 284 93578      0        NaN          0 4.356715e-17
## 285 68916      0        NaN          0 4.356715e-17
## 286 99524      0        NaN          0 4.356715e-17
## 287 94123      0        NaN          0 4.356715e-17
## 288 88661      0        NaN          0 4.356715e-17
## 289 65304      0        NaN          0 4.356715e-17
## 290 89412      0        NaN          0 4.356715e-17
## 291 65541      0        NaN          0 4.356715e-17
## 292 75560      0        NaN          0 4.356715e-17
```

```
## 293 92268      0        NaN          0 4.356715e-17
## 294 63694      0        NaN          0 4.356715e-17
## 295 59258      0        NaN          0 4.356715e-17
## 296 99480      0        NaN          0 4.356715e-17
## 297 68265      0        NaN          0 4.356715e-17
## 298 62591      0        NaN          0 4.356715e-17
## 299 64355      0        NaN          0 4.356715e-17
## 300 98182      0        NaN          0 4.356715e-17
## 301 94915      0        NaN          0 4.356715e-17
## 302 95525      0        NaN          0 4.356715e-17
## 303 92706      0        NaN          0 4.356715e-17
## 304 94847      0        NaN          0 4.356715e-17
## 305 67620      0        NaN          0 4.356715e-17
## 306 99892      0        NaN          0 4.356715e-17
## 307 77063      0        NaN          0 4.356715e-17
## 308 61925      0        NaN          0 4.356715e-17
## 309 68977      0        NaN          0 4.356715e-17
## 310 73239      0        NaN          0 4.356715e-17
## 311 75932      0        NaN          0 4.356715e-17
## 312 69378      4        NaN          0 1.190286e-01
## 313 77915      4        NaN          0 6.225029e-02
## 314 61863      4        NaN          0 9.997225e-03
## 315 95344      4        NaN          0 9.997225e-03
## 316 78379      1        NaN          0 3.648349e-03
## 317 92991      1        NaN          0 1.146265e-07
## 318 62499      7        NaN          0 1.108474e-05
## 319 65621      4        NaN          0 2.230405e-04
## 320 75933     13        NaN          0 3.903447e-03
## 321 98489      2        NaN          0 3.521575e-03
## 322 60203     12        NaN          0 1.280462e-03
## 323 67829     18        NaN          0 9.074478e-04
## 324 60851      6        NaN          0 3.516601e-01
## 325 74052     16        NaN          0 7.864214e-01
## 326 98826     10        NaN          0 6.989840e-02
## 327 65934      1        NaN          0 2.684046e-17
## 328 97338      1        NaN          0 2.062738e-17
## 329 99489      1        NaN          0 1.957038e-17
## 330 95299      1        NaN          0 2.194952e-17
## 331 96697      1        NaN          0 2.079526e-17
## 332 69099      1        NaN          0 2.725266e-05
## 333 98852      1        NaN          0 3.601754e-17
## 334 90995      2        NaN          0 1.737549e-03
## 335 70248      1        NaN          0 2.439549e-17
## 336 77651      1        NaN          0 2.621432e-17
## 337 77184      2        NaN          0 9.103444e-03
## 338 97312      1        NaN          0 3.762031e-17
## 339 72666      1        NaN          0 2.611942e-17
## 340 74048      1        NaN          0 2.645324e-17
## 341 62778      1        NaN          0 3.552328e-17
## 342 78856      1        NaN          0 5.152493e-18
## 343 67890      1        NaN          0 7.143847e-18
## 344 61408      1        NaN          0 6.310605e-18
## 345 99787      1        NaN          0 6.960912e-18
## 346 86422      1        NaN          0 3.914374e-18
```

```
## 347 70788      1        NaN           0 5.802374e-18
## 348 77228      1        NaN           0 9.397387e-04
## 349 69511      1        NaN           0 3.219770e-17
## 350 66182      1        NaN           0 2.820059e-17
## 351 71397      2        NaN           0 4.835429e-04
## 352 95065      1        NaN           0 8.163706e-03
## 353 81984      4        NaN           0 1.187126e-01
## 354 60437      1        NaN           0 2.483594e-17
## 355 80181      1        NaN           0 3.896146e-17
## 356 67698      1        NaN           0 2.724826e-17
## 357 95160      1        NaN           0 4.111361e-06
## 358 94771      1        NaN           0 5.861002e-02
## 359 98738      1        NaN           0 2.178643e-17
## 360 63372      2        NaN           0 6.262549e-04
## 361 95432      1        NaN           0 0.000000e+00
## 362 59269      1        NaN           0 0.000000e+00
## 363 63482      1        NaN           0 0.000000e+00
## 364 94860      1        NaN           0 0.000000e+00
## 365 89466      1        NaN           0 0.000000e+00
## 366 95666      1        NaN           0 0.000000e+00
## 367 89404      1        NaN           0 0.000000e+00
## 368 73564      1        NaN           0 0.000000e+00
## 369 64184      1        NaN           0 0.000000e+00
## 370 67547      1        NaN           0 0.000000e+00
## 371 67514      1        NaN           0 0.000000e+00
## 372 97267      1        NaN           0 0.000000e+00
## 373 64350      1        NaN           0 0.000000e+00
## 374 99577      1        NaN           0 0.000000e+00
## 375 91123      1        NaN           0 0.000000e+00
## 376 88204      1        NaN           0 3.959135e-17
## 377 97922      1        NaN           0 7.108826e-18
## 378 94768      1        NaN           0 8.995829e-18
## 379 81287      1        NaN           0 7.257309e-18
## 380 66203      1        NaN           0 6.032715e-18
## 381 82412      1        NaN           0 6.353455e-18
## 382 62098      1        NaN           0 9.621650e-18
```

```
ggarrange(dc_164,ec_164,cc_164,bc_164,ncol = 2, nrow = 2)
```

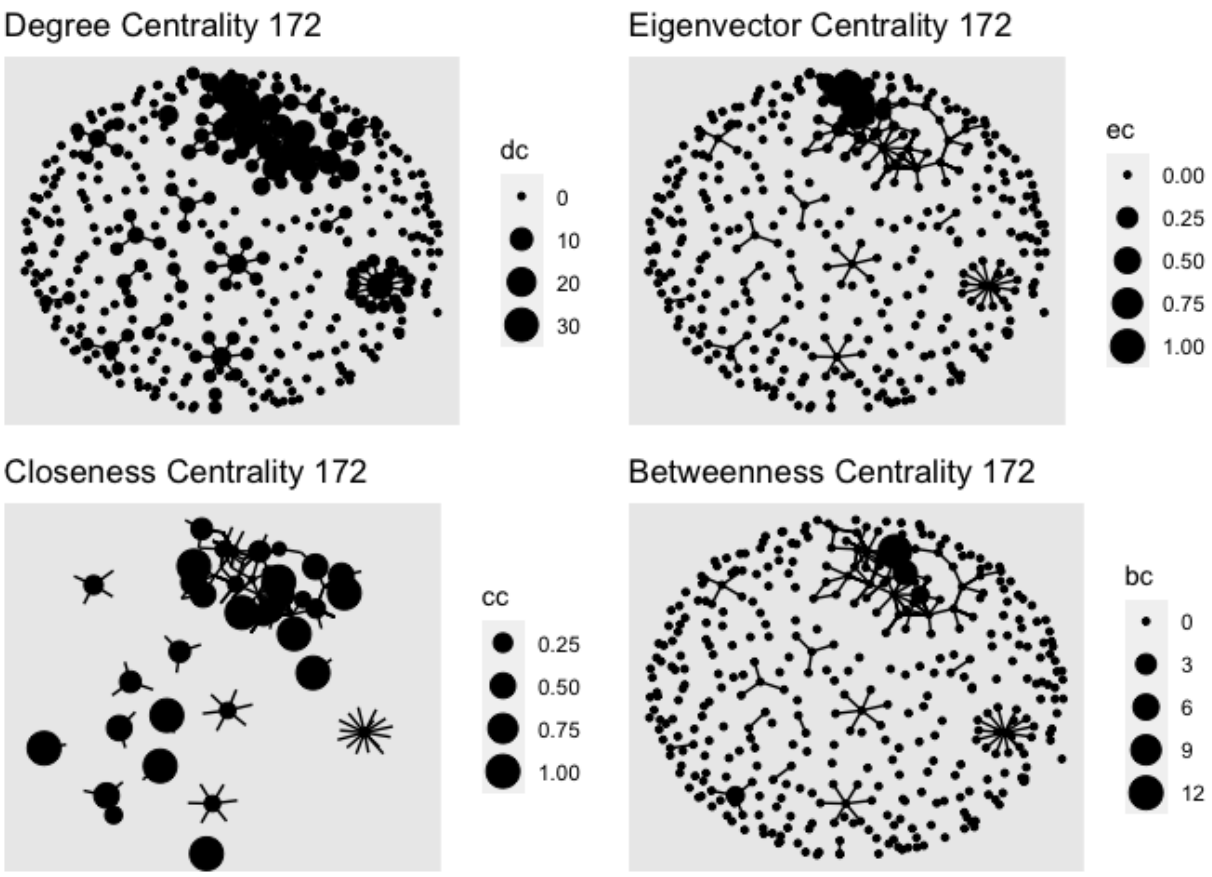
```
## Warning: Removed 293 rows containing missing values (geom_point).
```




```
dc_172 = ggraph(net_172, layout="kk") +
  geom_edge_link()+
  geom_node_point(aes(size=dc), show.legend=T) + ggtitle("Degree Centrality 172")

# Eigenvector Centrality
ec_172<-ggraph(net_172, layout="kk") +
  geom_edge_link()+
  geom_node_point(aes(size=ec), show.legend=T) + ggtitle("Eigenvector Centrality 172")

# Closness Centrality
cc_172<-ggraph(net_172, layout="kk") +
  geom_edge_link()+
  geom_node_point(aes(size=cc), show.legend=T) + ggtitle("Closeness Centrality 172")

# Betwenness Centrality
bc_172<-ggraph(net_172, layout="kk") +
  geom_edge_link()+
  geom_node_point(aes(size=bc), show.legend=T) + ggtitle("Betweenness Centrality 172")
```

```
ggarrange(dc_172,ec_172,cc_172,bc_172,ncol = 2, nrow = 2)
```

```
## Warning: Removed 345 rows containing missing values (geom_point).
```



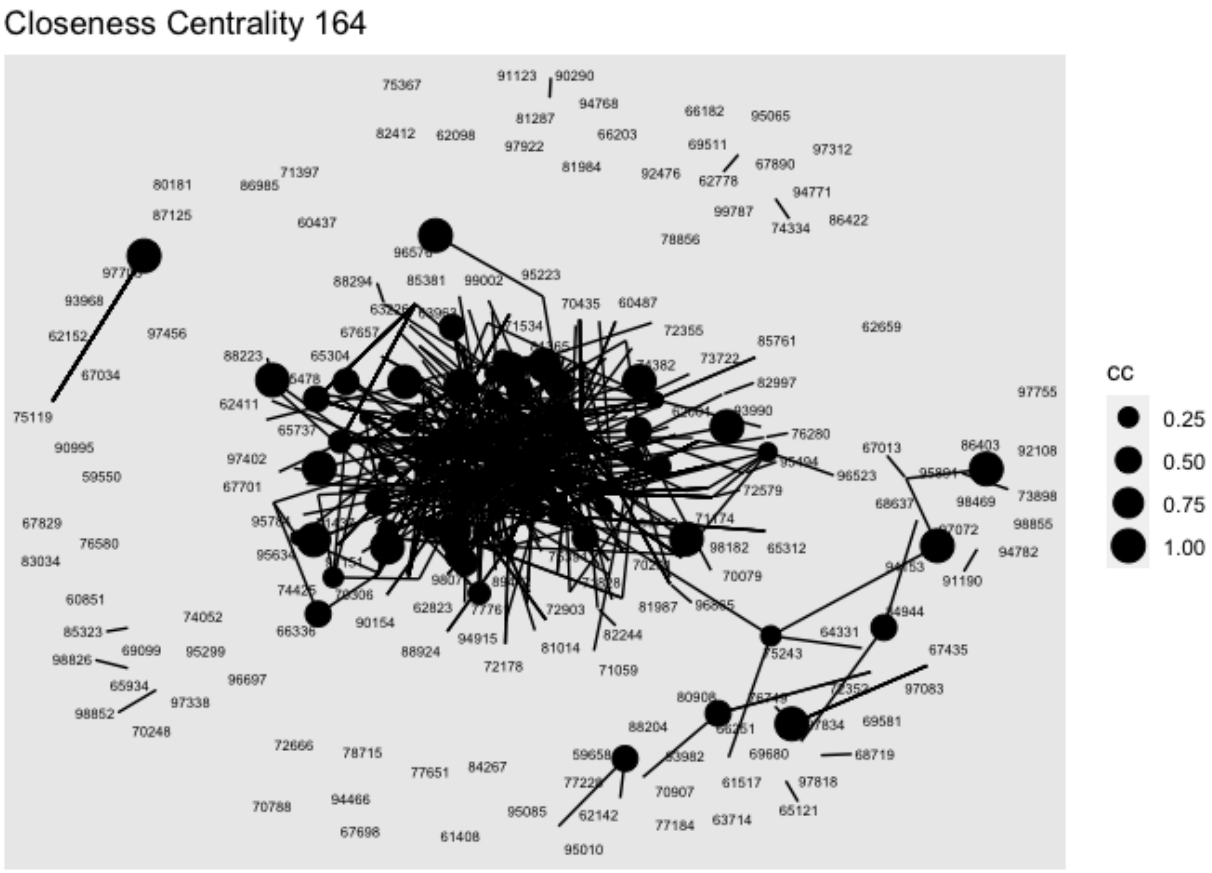
Based on the graph, seems like closeness centrality has clearer cluster center.

Characterize and discuss the relationship between centrality and other examiners'characteristics

```
ggraph(net_164, layout="kk") +
  geom_edge_link()+
  geom_node_point(aes(size=cc), show.legend=T) +geom_node_text(aes(label = centrality_164$id), repel=TRU
```

```
## Warning: Removed 293 rows containing missing values (geom_point).
```

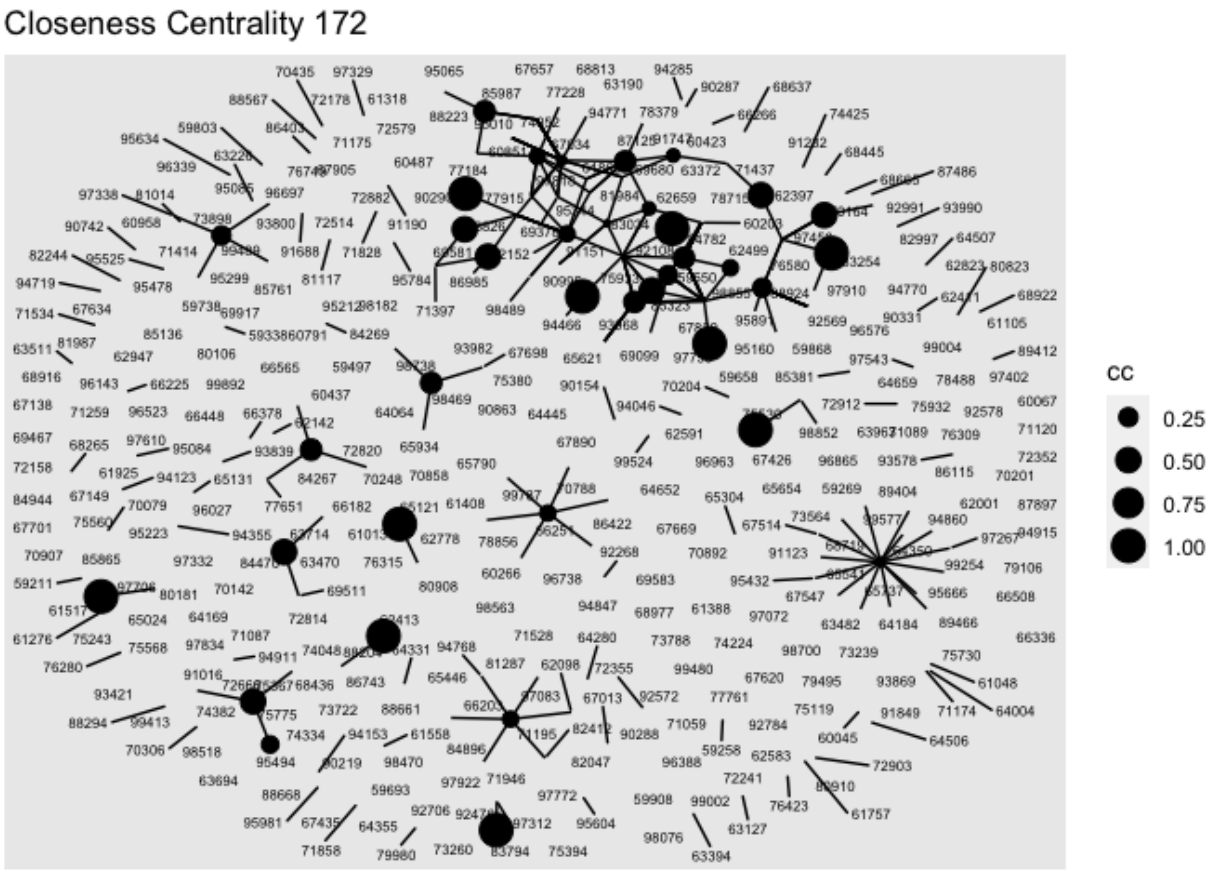
```
## Warning: ggrepel: 226 unlabeled data points (too many overlaps). Consider
## increasing max.overlaps
```




```
ggraph(net_172, layout="kk") +
  geom_edge_link()+
  geom_node_point(aes(size=cc), show.legend=T) +geom_node_text(aes(label = centrality_172$id), repel=TRU
```

```
## Warning: Removed 345 rows containing missing values (geom_point).
```

```
## Warning: ggrepel: 7 unlabeled data points (too many overlaps). Consider
## increasing max.overlaps
```



Gather all examiner characteristics

```
examiner = df %>% select(examiner_id,examiner_art_unit,gender,race,tenure)
examiner = distinct(examiner)
```

Examiner that are in group 164 and has the highest closeness centrality

```
max_cc_164 = max(centrality_164$closeness[!is.na(centrality_164$closeness)])
max_cc_164_id = centrality_164 %>% filter(centrality_164$closeness ==max_cc_164) %>%select(id)
max_cc_164_id = max_cc_164_id %>% mutate(id = as.numeric(id))
max_cc_164_info = examiner %>%filter(examiner_id == max_cc_164_id$id)

table(max_cc_164_info$gender)
```

```
##
## female   male
##    252    323
```

```
table(max_cc_164_info$race)
```

```
##
##    asian    black hispanic    white
##      163       43        2      367
```

Examiners that has higher closeness centrality in group 164, are more likely to be while male.

Examiner that are in group 172 and has the highest closeness centrality

```
max_cc_172 = max(centrality_172$closeness[!is.na(centrality_172$closeness)])
max_cc_172_id = centrality_172 %>% filter(centrality_172$closeness ==max_cc_172) %>%select(id)
max_cc_172_id = max_cc_172_id %>% mutate(id = as.numeric(id))
max_cc_172_info = examiner %>%filter(examiner_id == max_cc_172_id$id)

table(max_cc_172_info$gender)
```

```
##
## female   male
##     79    366
```

```
table(max_cc_172_info$race)
```

```
##
##    asian hispanic    white
##       63       43      339
```

The examiners that has higher closeness centrality in group 172 are mostly male comparing to group 164. Also, there are more Hispanic examiners that are influencial in this group.