CSCI6444 Project I Report

#1.2 How do we load and simplify data

Below is the code we used for loading data and the simplification so that we can experiment other functions on them:

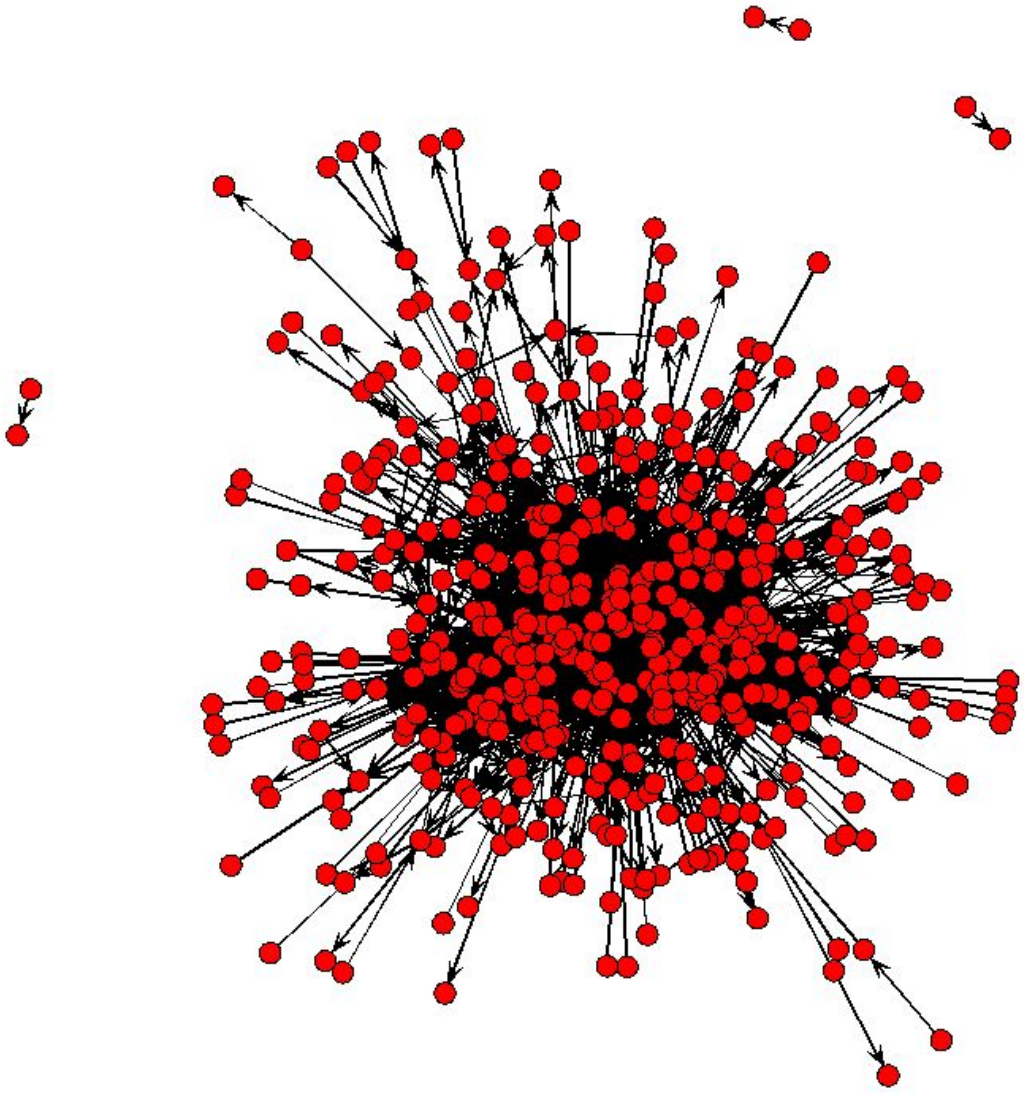
```
//first get the igraph from the data frame
email.igraph<-graph.data.frame(email.EU, directed = TRUE)

//then get the adjacency matrix
email.adj<-as_adjacency_matrix(email.igraph,type="both",names=TRUE,sparse=FALSE)

//next simplify the graph by extract a part of it
email.igraph.sim<-induced_subgraph(email.igraph, 1:500)

//create the simplified adj matrix
email.adj.sim<-as_adjacency_matrix(email.igraph.sim,
type="both",names=TRUE,sparse=FALSE)

//create the network so that we can get rid of isolated nodes(degree = 0, use (sum(degree < 1))
to check if there is any isolated node)
email.net.sim<-as.network.matrix(email.adj.sim)

//delete isolated nodes
email.adj.sim<-delete.vertices(email.net.sim, which(degree(email.net.sim) < 1))

//convert the network back to the adj matrix
email.adj.sim<-as.matrix.network(email.adj.sim)

//convert the adj matrix back to igraph so that we can use those functions.
email.igraph.sim<-graph_from_adjacency_matrix(email.adj.sim, mode = "directed")
```

#2 Task What we learned from the data

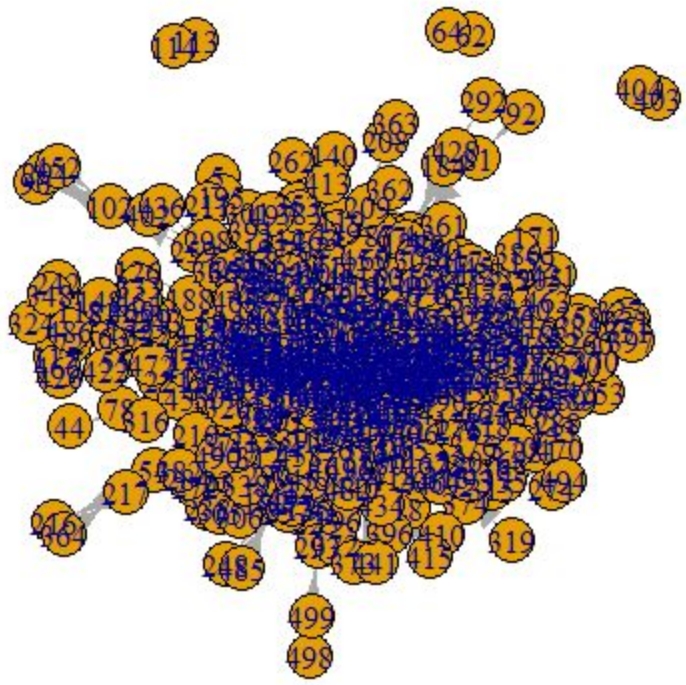
The size of data is very large and the data type is relatively random. It is difficult to find the relationship among the data directly. So it is hard to extract useful information from the data. Therefore, one needs to trim the data and store it into a specific format. Afterwards, one can use the built-in functions to get desired data.

#3 Task Experiment some functions showed in slides

plot(email.net.sim). Below is the plot we got from this simplified network:



Also, we tried plot(email.igraph.sim):



Seems that plot of 500 nodes is still too crowded.

is.simple(email.igraph.sim):

```
> is.simple(email.igraph.sim)
[1] TRUE
```

page_rank(email.igraph.sim):

```
> page_rank(email.igraph.sim)
$vector
          2           3           4           5           6           7           8           9          10
0.017542738 0.004468490 0.046626837 0.000929434 0.049150920 0.019101495 0.001970026 0.003453485 0.008897894
         11          12          14          15          16          17          18          19          20
0.006265047 0.005769643 0.012282456 0.001763381 0.008948736 0.011760856 0.002775888 0.004799779 0.003289341
         21          22          23          24          25          26          27          28          29
0.008895301 0.000930181 0.005346807 0.003400838 0.002017590 0.005131789 0.009048094 0.004073598 0.003645076
         30          31          32          34          35          36          37          38          39
0.005769051 0.004047324 0.000809499 0.006743609 0.008058903 0.002203322 0.004361626 0.008530927 0.001009496
         40          42          43          44          45          46          47          48          49
0.001738560 0.000735982 0.003535613 0.002348209 0.001896737 0.005741810 0.007702584 0.001049804 0.001507773
         50          51          52          53          54          55          56          57          58
0.002791172 0.004835741 0.001478838 0.004369737 0.000860151 0.005529140 0.016917029 0.007099523 0.003990855
         59          60          62          63          64          66          67          68          69
0.000800335 0.001249359 0.001361567 0.002009509 0.000735982 0.003350395 0.000735982 0.001256137 0.002447788
         70          71          72          73          74          75          76          77          78
0.000735982 0.001602611 0.001146284 0.007250793 0.005890203 0.001972008 0.002896247 0.003940853 0.000735982
         79          80          81          82          83          84          85          86          87
0.001171261 0.000735982 0.001361567 0.000735982 0.005918643 0.008113469 0.001693538 0.004238379 0.000735982
         88          89          90          92          93          94          95          96          97
0.005352238 0.001082780 0.002490423 0.000735982 0.004484305 0.008819583 0.002130519 0.009363397 0.002299472
         98          99         100         101         102         103         104         105         106
0.007325598 0.000849070 0.001794168 0.006224623 0.002064047 0.013173171 0.003061791 0.001352946 0.005618883
        107         108         109         110         111         112         113         114         115
```

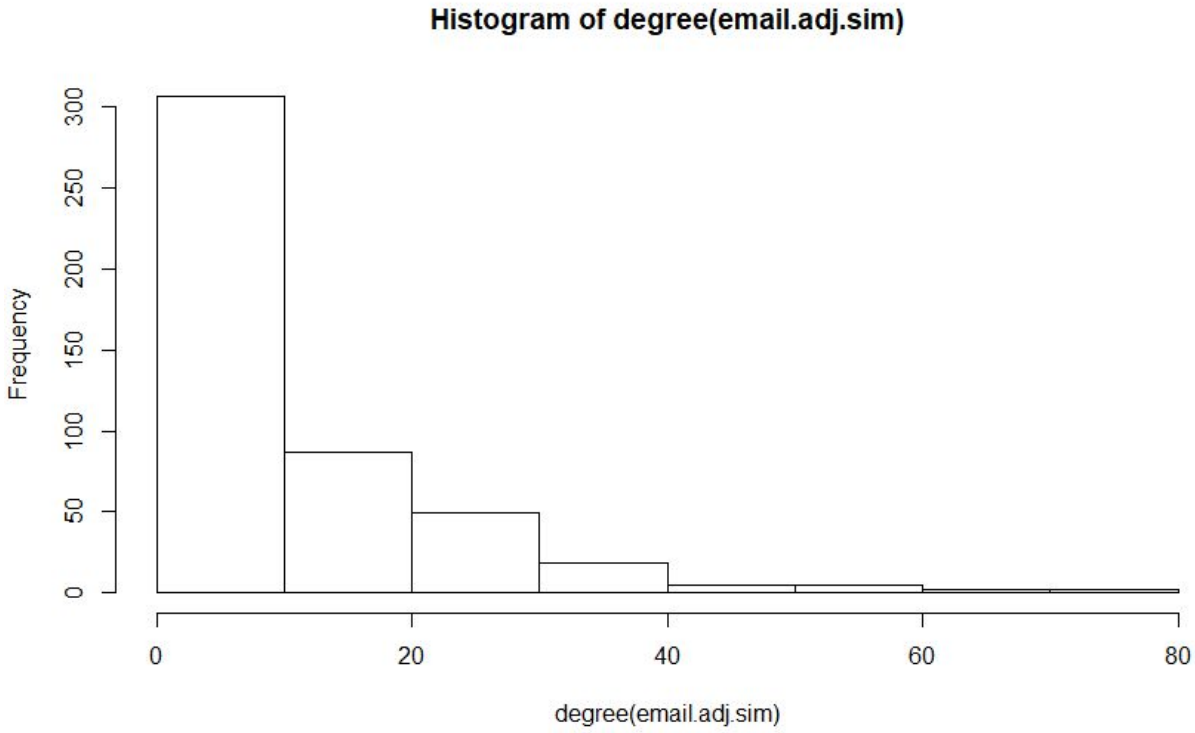
alpha_centrality(email.igraph.sim):

```
> alpha_centrality(email.igraph.sim)
          2           3           4           5           6           7           8           9          10
1.847283e+11 6.319454e+08 1.289521e+11 7.216000e+03 1.217743e+11 1.676580e+09 1.238270e+07 7.869032e+06 7.041832e+08
         11          12          14          15          16          17          18          19          20
7.090928e+08 1.437286e+09 9.266183e+09 6.598260e+05 1.487915e+10 7.863035e+09 2.153864e+10 2.153864e+10 6.460207e+08
         21          22          23          24          25          26          27          28          29
1.973810e+09 6.094490e+05 4.550422e+07 3.343139e+07 6.544340e+09 6.210938e+10 6.201686e+10 7.082816e+06 4.655174e+10
         30          31          32          34          35          36          37          38          39
3.954851e+10 1.207282e+07 8.691000e+03 1.196571e+10 7.987750e+09 3.760051e+07 1.944761e+09 1.944761e+09 4.694090e+05
         40          42          43          44          45          46          47          48          49
3.276963e+06 1.000000e+00 2.054283e+10 2.442750e+05 2.442740e+05 7.015864e+09 8.535569e+08 1.718700e+04 6.544340e+09
         50          51          52          53          54          55          56          57          58
8.300610e+09 8.300610e+09 1.946010e+10 1.946010e+10 1.021100e+04 1.436818e+09 1.436818e+09 2.151729e+10 6.337093e+08
         59          60          62          63          64          66          67          68          69
2.800000e+01 2.113910e+05 2.000000e+00 7.109959e+06 1.000000e+00 1.202494e+08 1.000000e+00 3.748781e+07 3.748781e+07
         70          71          72          73          74          75          76          77          78
1.000000e+00 6.393667e+06 1.008858e+06 6.448557e+08 6.331598e+06 1.807907e+06 1.008857e+06 7.783600e+05 1.000000e+00
         79          80          81          82          83          84          85          86          87
9.842601e+06 1.000000e+00 2.000000e+00 1.000000e+00 1.128265e+10 6.544338e+09 1.181287e+09 2.464480e+09 1.000000e+00
         88          89          90          92          93          94          95          96          97
1.164872e+09 9.804831e+06 6.000000e+00 1.000000e+00 8.114757e+08 8.114757e+08 6.216885e+08 6.216393e+08 4.764390e+05
```

cliques(email.igraph.sim, min = 9)(There are so many of them):

```
[[235]]
+ 9/475 vertices, named, from 1e53569:
[1] 83  84  88  103 104 175 215 356 454

[[236]]
+ 9/475 vertices, named, from 1e53569:
[1] 83  84  88  96  104 175 215 356 454

[[237]]
+ 9/475 vertices, named, from 1e53569:
[1] 83  88  96  104 146 175 215 356 454

[[238]]
+ 9/475 vertices, named, from 1e53569:
[1] 83  84  88  96  103 104 215 356 454

[[239]]
+ 9/475 vertices, named, from 1e53569:
[1] 83  84  88  96  103 104 175 356 454

[[240]]
+ 9/475 vertices, named, from 1e53569:
[1] 84  88  96  103 104 175 215 356 454

[[241]]
+ 9/475 vertices, named, from 1e53569:
[1] 83  84  86  88  96  104 175 215 356

[[242]]
+ 9/475 vertices, named, from 1e53569:
[1] 83  84  88  96  103 104 175 215 356

[[243]]
+ 9/475 vertices, named, from 1e53569:
[1] 83  84  88  96  103 104 175 215 454
```

hist(degree(email.adj.sim)):



#4 Task Explore other functions in the igraph package – at least 10 of them

After the simple simplification of the original data, we experiment below functions. Here are the results:

is.directed(email.net.sim)

is.weighted(email.igraph.sim)

is.connected(email.adj.sim)

```
> is.directed(email.net.sim)
[1] TRUE
> is.weighted(email.igraph.sim)
[1] FALSE
> is.connected(email.adj.sim)
[1] FALSE
```

dfs(email.igraph.sim,1)

```
> dfs(email.igraph.sim, 1)
$root
[1] 0

$neimode
[1] "out"

$order
+ 475/475 vertices, named, from 1e53569:
  [1] 2   3   4   5   6   7   8   9   10  11  12  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31
 [30] 32  34  35  36  37  38  39  40  42  43  44  45  46  47  48  49  50  51  52  53  54  55  56  57  58  59  60  62  63
 [59] 64  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  92  93  94
 [88] 95  96  97  98  99  100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 121 122 123 124
[117] 125 126 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 145 146 147 148 149 150 151 152 153 154 155
[146] 156 157 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185
[175] 186 187 188 189 190 191 192 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215
[204] 216 217 218 219 220 222 223 224 225 226 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246
[233] 247 248 249 250 251 252 253 254 255 256 257 258 259 260 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276
[262] 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305
+ ... omitted several vertices

$order.out
NULL

$father
NULL

$dist
NULL
```

bfs(email.igraph.sim,4)

```
> bfs(email.igraph.sim,4)
$root
[1] 4

$neimode
[1] "out"

$order
+ 475/475 vertices, named, from 1e53569:
  [1] 5   2   3   4   6   7   8   9   10  11  12  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31
 [30] 32  34  35  36  37  38  39  40  42  43  44  45  46  47  48  49  50  51  52  53  54  55  56  57  58  59  60  62  63
 [59] 64  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  92  93  94
 [88] 95  96  97  98  99  100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 121 122 123 124
[117] 125 126 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 145 146 147 148 149 150 151 152 153 154 155
[146] 156 157 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185
[175] 186 187 188 189 190 191 192 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215
[204] 216 217 218 219 220 222 223 224 225 226 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246
[233] 247 248 249 250 251 252 253 254 255 256 257 258 259 260 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276
[262] 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305
+ ... omitted several vertices

$rank
NULL

$father
NULL

$pred
NULL

$succ
NULL

$dist
NULL
```

count_triangles(email.igraph.sim)

```
> count_triangles(email.igraph.sim)
  [1] 123  10   0   0 168  36   3   9  66  22   6  60   9  29  83   0  16   3  76   1   1   9   0   1  95  10   3  88  11
 [30]   0  29  12   4   0 101   3   0   0  30   0   2  56  15   3   0   0  44   1 103   0   0 176  73  27   2   3   0   1
 [59]   0  16   0   0  28   0   2   0 110  93  16  32  44   0   9   0   0   0 196 195   7 125   0 191   1   0   0   0  79
 [88]  10 250  25 123  10   0  64   0 351 111  31 130  26  48  53   7  16   5   0   0   0  52  28   0   0  15   1 204   0
[117]  11   0  31  66  11   5  53 103  73   0  29   0  13   0   0  16  40   0  23  59  53   0  50  73  12   0  33  22 171
[146]  28  36   0   1   6  85 418   8   3   1   6  15  28  54   0   0  52 182 353  27   9   1  20   6  30   0   0   0  23
[175]   8   3   0  29  19 147  41  21   0   0   6   5  10  66  27   1  81  15   0   0 155   0   0   1   0   1   1   3 257
[204]   0   0   1   2   0  49   5  56   0  22  89   0  39   5  52   3  40  77  72  20   0  31  92  30   0   2 144  50   0
[233] 100   0   8   1   0   1   0   1   2 109   0   1   0   0   0   3   1   7   0  12   0   0   0  34   0  11   0  15   0
[262]  46  38   6 195   0  47 219   0  40   6  85   0  12   1   2   0   0   0  45  41 104   0  46  39   0   6   0  40   0
[291]   1   0   3   7   1  21   0   5  13   0   0  35  38   0   0   2   1 274   0   0 119   0  50   9   1   0  25   0   0
[320]  27   0  36   0   2   0  91   2 110  41   0  26   1   0 192  15   0  17   0  64   0 137   1   1   3   0   0   0   0
[349]   0  14   0  14   2   0 122   1   1   0  44   1  38   0 190  69 111   0   0   0  21   0   0 207   0  12   1 113  32
[378]  29  14   0   0   4   4   0  54   0   0   0   7   4   4  69 107   0  13   6   0   0   0   0   0   1   1  18   0   0
[407]   1  45   0   0   9   6   1   0   9   1  10   0  69   8   5   0   4  13  12   0   1  25   0  22   0   6 128   0   4
[436]   2  15 116   0   0  20   0   0   0   0   0  91   5   0  16   1  31   0 151   0  58  66   1  14   0   0 348   1   0
[465]   1   1  17   0   0   0   0   1   0   0   1
```

degree(email.igraph.sim, "156")

```
> degree(email.adj.sim, "156")
  [1] 27  9  7  1 60 15  4  7 22 13  4 20  8 10 24  1 12  4 23  2  2  8  3  2 20 10  3 19 11  1 12 12  6  1 30  4  3  1
 [39] 11  1  4 21 11  5  3  1 18  2 18  1  1 45 21 18  3  3  1  2  1 11  1  1 13  1  3  1 29 27  8 14 18  1  6  1  2  1
 [77] 29 36  5 25  1 33  3  1  1  1 29 10 54 15 30  5  1 29  4 60 23 14 30 12 12 21  6 11  7  1  1  1 18 13  1  1 10  2
[115] 47  1 10  1 16 21  7  7 28 27 20  1 13  1  9  2  1 12 16  1 10 17 20  2 17 36  9  1 15 14 39 10 15  1  3  7 24 79
[153]  5  3  2  4 14 15 19  1  1 19 34 49 11 11  2 12  5 12  1  1  1 21  7  6  2 14 10 37 16 12  1  1  8  5  9 26 23  3
[191] 24 10  1  1 39  1  4  2  1  4  2  3 40  1  3  2  3  1 18  4 15  1 21 32  2 14  5 19  6 17 28 24 14  1 20 40 13  1
[229]  7 40 20  1 37  1  8  2  1  5  1  2  3 31  1  2  1  1  1  4  5  6  3  6  1  3  1 13  1  7  1  9  1 16 17  6 33  1
[267] 22 59  1 18  5 26  1 12  3  3  1  2  1 21 21 30  1 16 15  1 10  1 20  1  2  4  4  6  2 11  2  5 13  1  1 22 17  1
[305]  2  3  5 70  1  1 26  1 21  6  2  1 16  1  1 12  1 17  1  3  1 19  6 30 21  1 15  2  1 41 11  1 12  2 18  1 24  4
[343]  2  3  2  2  1  1  2 10  2 11  3  1 37  3  2  1 22  2 16  1 51 30 29  1  1  1 15  1  1 72  3  9  2 39 15 11 10  1
[381]  1  5  6  2 23  1  1  1  5  6  4 21 29  1  8  8  1  3  1  1  1  2  2 11  1  1  2 19  1  2  7  5  2  1  9  2  8  1
[419] 21  6  9  1  6 10  9  1  2 12  1 15  1  4 26  2  5  3 13 41  1  1 16  1  1  2  1  1 37  9  1  8  2 15  1 33  1 29
[457] 21  2  8  1  1 69  2  1  2  2  8  1  1  1  1  2  1  2  3
```

components(email.igraph.sim)

```
> components(email.adj.sim)
[1] 475
```

head(components(email.igraph.sim))

V(email.igraph.sim)

```
> head(components(email.adj.sim))
[1] 475
> V(email.igraph.sim)
+ 475/475 vertices, named, from 1e53569:
  [1] 2   3   4   5   6   7   8   9   10  11  12  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31
 [30] 32  34  35  36  37  38  39  40  42  43  44  45  46  47  48  49  50  51  52  53  54  55  56  57  58  59  60  62  63
 [59] 64  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  92  93  94
 [88] 95  96  97  98  99  100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 121 122 123 124
[117] 125 126 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 145 146 147 148 149 150 151 152 153 154 155
[146] 156 157 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185
[175] 186 187 188 189 190 191 192 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215
[204] 216 217 218 219 220 222 223 224 225 226 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246
[233] 247 248 249 250 251 252 253 254 255 256 257 258 259 260 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276
[262] 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305
+ ... omitted several vertices
```

edges(email.igraph.sim)

```
> edges(email.igraph.sim)
[[1]]
IGRAPH 1e53569 DN-- 475 2453 --
+ attr: name (v/c)
+ edges from 1e53569 (vertex names):
  [1] 6 ->4   10->7   14->6   16->6   17->6   17->16 19->6   19->18 22->21 24->23 25->4   25->14 27->2   27->26 30->2   30->6
 [17] 30->29 31->23 31->24 36->35 38->21 38->37 42->6   43->27 45->44 46->16 46->17 47->7   48->6   49->25 51->6   51->50
 [33] 52->2   53->2   53->27 53->30 53->43 53->52 56->12 56->14 56->55 57->2   57->19 58->6   58->56 59->56 59->58 64->62
 [49] 66->17 67->6   69->10 69->36 69->38 69->68 70->11 73->14 73->20 73->56 74->9   74->14 74->28 74->56 74->63 74->71
 [65] 74->73 75->56 75->73 75->74 76->14 76->56 76->72 76->73 76->74 76->75 77->56 77->63 77->73 77->74 77->75 77->76
 [81] 78->21 79->6   80->6   81->4   82->74 83->2   83->6   83->27 83->30 83->34 83->53 83->57 84->2   84->6   84->27 84->29
 [97] 84->30 84->35 84->46 84->49 84->51 84->53 84->57 84->83 85->84 86->2   86->27 86->57 86->83 86->84 87->6   88->2
[113] 88->27 88->30 88->53 88->57 88->83 88->84 88->85 88->86 92->81 94->47 94->93 95->2   95->4   95->35 95->84 95->86
+ ... omitted several edges

attr(,"class")
[1] "igraph.edge"
```

vertex_attr(email.igraph.sim)

```
> vertex_attr(email.igraph.sim)
$name
  [1] "2"   "3"   "4"   "5"   "6"   "7"   "8"   "9"   "10"  "11"  "12"  "14"  "15"  "16"  "17"  "18"  "19"  "20"  "21"
 [20] "22"  "23"  "24"  "25"  "26"  "27"  "28"  "29"  "30"  "31"  "32"  "34"  "35"  "36"  "37"  "38"  "39"  "40"  "42"
 [39] "43"  "44"  "45"  "46"  "47"  "48"  "49"  "50"  "51"  "52"  "53"  "54"  "55"  "56"  "57"  "58"  "59"  "60"  "62"
 [58] "63"  "64"  "66"  "67"  "68"  "69"  "70"  "71"  "72"  "73"  "74"  "75"  "76"  "77"  "78"  "79"  "80"  "81"  "82"
 [77] "83"  "84"  "85"  "86"  "87"  "88"  "89"  "90"  "92"  "93"  "94"  "95"  "96"  "97"  "98"  "99"  "100" "101" "102"
 [96] "103" "104" "105" "106" "107" "108" "109" "110" "111" "112" "113" "114" "115" "116" "117" "118" "119" "121" "122"
[115] "123" "124" "125" "126" "128" "129" "130" "131" "132" "133" "134" "135" "136" "137" "138" "139" "140" "141" "142"
[134] "143" "145" "146" "147" "148" "149" "150" "151" "152" "153" "154" "155" "156" "157" "159" "160" "161" "162" "163"
[153] "164" "165" "166" "167" "168" "169" "170" "171" "172" "173" "174" "175" "176" "177" "178" "179" "180" "181" "182"
[172] "183" "184" "185" "186" "187" "188" "189" "190" "191" "192" "194" "195" "196" "197" "198" "199" "200" "201" "202"
[191] "203" "204" "205" "206" "207" "208" "209" "210" "211" "212" "213" "214" "215" "216" "217" "218" "219" "220" "222"
[210] "223" "224" "225" "226" "228" "229" "230" "231" "232" "233" "234" "235" "236" "237" "238" "239" "240" "241" "242"
[229] "243" "244" "245" "246" "247" "248" "249" "250" "251" "252" "253" "254" "255" "256" "257" "258" "259" "260" "262"
[248] "263" "264" "265" "266" "267" "268" "269" "270" "271" "272" "273" "274" "275" "276" "277" "278" "279" "280" "281"
[267] "282" "283" "284" "285" "286" "287" "288" "289" "290" "291" "292" "293" "294" "295" "296" "297" "298" "299" "300"
[286] "301" "302" "303" "304" "305" "306" "307" "308" "309" "310" "311" "312" "313" "314" "315" "316" "317" "318" "319"
[305] "320" "321" "322" "323" "324" "325" "326" "327" "328" "329" "330" "331" "332" "333" "334" "335" "336" "337" "338"
[324] "339" "340" "341" "342" "343" "344" "345" "346" "347" "348" "349" "350" "351" "352" "353" "354" "355" "356" "357"
[343] "358" "359" "361" "362" "363" "364" "365" "366" "367" "368" "369" "370" "371" "372" "373" "374" "375" "376" "377"
[362] "378" "379" "380" "381" "382" "383" "384" "385" "386" "387" "388" "389" "390" "391" "392" "393" "394" "395" "396"
[381] "397" "398" "399" "400" "401" "402" "403" "404" "405" "406" "407" "408" "409" "410" "411" "412" "413" "414" "415"
[400] "416" "417" "418" "419" "420" "421" "422" "424" "425" "426" "428" "429" "430" "431" "432" "433" "434" "435" "436"
[419] "438" "439" "440" "441" "442" "443" "444" "445" "446" "448" "449" "450" "452" "453" "454" "455" "456" "457" "458"
[438] "459" "460" "461" "462" "463" "464" "465" "466" "467" "468" "469" "470" "471" "472" "473" "475" "476" "477" "478"
[457] "479" "482" "484" "485" "486" "487" "488" "489" "490" "491" "492" "493" "494" "495" "496" "497" "498" "499" "500"
```

is.simple(email.igraph.sim)

```
> is.simple(email.igraph.sim)
[1] TRUE
```

#5 Task

a.To get the central person, we calculate the eigenvector centrality of all nodes and find the nodes whose centrality is 1:

```
> email.igraph<-read.graph("email-EU.edges")
> email.e_cen<-eigen_centrality(email.igraph)
> view(email.e_cen)
> which(email.e_cen[["vector"]] == 1)
[1] 487
```

Now we know that the central person's index is 487.

b.The longest path:

```
> get_diameter(email.igraph)
+ 14/32431 vertices, from a410462:
 [1] 17764 16732  8856  3760  2137  1868  1502  1501  1381  1338  1271  1218   750   666
```

c.Largest cliques(there are numbers of them. The screenshot below just shows part of them):

```
> largest_cliques(email.igraph)
[[1]]
+ 12/32431 vertices, from a410462:
 [1] 951 215 175  84  83  88 356 503 454 280  96 889

[[2]]
+ 12/32431 vertices, from a410462:
 [1] 951 215 175  84  83  88 356 503 454 280  96 104

[[3]]
+ 12/32431 vertices, from a410462:
 [1]   103   175  6713   326    30   503    84   224  1024 12888   174   682

[[4]]
+ 12/32431 vertices, from a410462:
 [1]   103   175   224   326    84   503    30  1024   682   174  1023 12888

[[5]]
+ 12/32431 vertices, from a410462:
 [1]   103   175   224   326    84   503    30  1024    83  1023 12888  8014

[[6]]
+ 12/32431 vertices, from a410462:
 [1]   103   175   224   326    84   503    30  1024    83  1023 12888   174

[[7]]
+ 12/32431 vertices, from a410462:
 [1]   103   175   215   560   682 12888    30   174   326   503  1023  1024

[[8]]
+ 12/32431 vertices, from a410462:
 [1]   103   175   215    84   503   682   174   326  1023  1024    30 12888

[[9]]
+ 12/32431 vertices, from a410462:
 [1]   103   175   215    84   503    83   326  1024  1023    30 12888  8014

[[10]]
+ 12/32431 vertices, from a410462:
 [1]   103   175   215    84   503    83   326  1024  1023    30 12888   174

[[11]]
+ 12/32431 vertices, from a410462:
 [1]   103   175   215    84   503    83    88  1024  1023  8014    30 12888
```

d.To calculate the egocentric network we first convert the graph to an adjacency matrix, which takes some time. Then, we used ego.extract() to get the ego of this graph. Below just display part of it:

```
$`964`
     [,1] [,2]
[1,]    0    0
[2,]    1    0

$`965`
     [,1] [,2]
[1,]    0    0
[2,]    1    0

$`966`
      [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13] [,14] [,15]
 [1,]    0    1    1    1    1    1    0    0    0      0      0      0      0      0      0
 [2,]    0    0    0    0    0    0    0    0    0      0      0      0      0      0      0
 [3,]    0    1    0    0    0    0    0    0    0      0      0      0      0      0      0
 [4,]    0    1    1    0    0    0    0    0    0      0      0      0      0      0      0
 [5,]    0    0    0    0    0    0    0    0    0      0      0      0      0      0      0
 [6,]    0    0    0    0    0    0    0    0    0      0      0      0      0      0      0
 [7,]    1    1    0    0    0    0    0    0    0      0      0      0      0      0      0
 [8,]    1    0    0    0    0    0    0    0    0      0      0      0      0      0      0
 [9,]    1    1    1    1    0    0    1    0    0      0      0      0      0      0      0
[10,]    1    0    0    0    0    0    0    0    1      0      0      0      0      0      0
[11,]    1    1    1    1    0    0    0    0    1      0      0      0      0      0      0
[12,]    1    0    0    1    0    0    0    0    0      0      0      0      0      0      0
[13,]    1    0    0    1    0    0    0    0    0      0      0      0      0      0      0
[14,]    1    0    0    0    0    0    0    0    0      0      0      0      0      0      0
[15,]    1    0    0    0    0    0    0    0    0      0      0      0      0      0      0

$`967`
      [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13] [,14] [,15] [,16] [,17] [,18] [,19] [,20]
 [1,]    0    1    1    1    1    1    1    1    1      1      1      1      1      1      1      1      1      1      1
 [2,]    0    0    0    0    0    0    0    0    0      0      0      0      0      0      0      0      0      0      0
 [3,]    0    1    0    0    0    0    0    0    0      0      0      0      0      0      0      0      0      0      0
 [4,]    0    1    1    0    0    0    0    0    0      0      0      0      0      0      0      0      0      0      0
 [5,]    0    0    0    1    0    0    0    0    0      0      0      0      0      0      0      0      0      0      0
 [6,]    0    0    0    0    1    0    0    0    0      0      0      0      0      0      0      0      0      0      0
 [7,]    0    0    1    1    0    0    0    0    0      0      0      0      0      0      0      0      0      0      0
      [,21] [,22] [,23] [,24] [,25] [,26] [,27] [,28] [,29] [,30] [,31] [,32] [,33] [,34] [,35] [,36] [,37] [,38] [,39]
 [1,]     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
 [2,]     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
 [3,]     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
 [4,]     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
 [5,]     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
 [6,]     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
 [7,]     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
      [,40] [,41] [,42] [,43] [,44] [,45] [,46] [,47] [,48] [,49] [,50] [,51] [,52] [,53] [,54] [,55] [,56] [,57] [,58]
```

e.Power centrality(part of it):

```
> power_centrality(email.igraph)
  [1]  0.000000e+00  4.362452e-17 -9.201381e-17 -4.726623e-17  0.000000e+00 -2.316975e-16  5.499565e-16  0.000000e+00
  [9] -1.434727e-16  1.139630e-16  2.008202e-16  1.600062e-16  0.000000e+00  4.204830e-17  0.000000e+00  9.711159e-17
 [17] -4.638120e-17  0.000000e+00 -7.801761e-16  0.000000e+00 -8.575858e-17 -5.016989e-17  0.000000e+00  2.412536e-16
 [25]  6.595945e-17  0.000000e+00 -4.538367e-17  1.131961e-16  0.000000e+00  2.666330e-16  2.825794e-16  0.000000e+00
 [33]  0.000000e+00  0.000000e+00  1.871740e-17 -2.992577e-16  0.000000e+00  4.068604e-16 -1.907256e-16  0.000000e+00
 [41]  0.000000e+00 -1.961088e-16 -4.367011e-16  0.000000e+00  3.558869e-17  2.261141e-16  6.035998e-17 -4.003560e-16
 [49]  4.659453e-17  0.000000e+00 -7.630974e-16  7.921321e-17 -1.412231e-16 -3.438645e-16  0.000000e+00  3.136069e-16
 [57] -4.262583e-16  3.190152e-16  7.037994e-16  0.000000e+00  0.000000e+00  0.000000e+00  0.000000e+00  3.558869e-17
 [65]  0.000000e+00 -4.251084e-16 -1.961088e-16  0.000000e+00  7.008703e-16  2.364089e-16 -1.911393e-17  0.000000e+00
 [73]  8.568174e-16  1.536327e-15  2.926473e-15  5.836910e-15  1.094921e-14 -5.016989e-17 -1.961088e-16 -1.961088e-16
 [81] -1.167754e-17  1.571916e-15 -4.752770e-16  3.745864e-16  4.101751e-16 -5.523412e-16 -1.961088e-16 -3.741143e-16
 [89] -1.864597e-17  0.000000e+00  0.000000e+00  2.391115e-17  0.000000e+00 -3.238515e-17  1.526437e-17 -2.667140e-16
 [97]  8.693361e-16  1.919254e-17 -2.613928e-16 -8.096477e-17 -3.368551e-16  8.175899e-17 -6.858804e-16  2.329477e-16
[105]  1.374432e-14 -5.005803e-16 -8.063883e-16 -6.657304e-16 -4.336848e-17  4.848313e-16  2.871720e-16  2.986456e-19
[113]  0.000000e+00  3.558869e-17  1.098480e-14  1.305149e-15  8.324398e-15  8.359987e-15  2.617028e-16  0.000000e+00
[121]  2.415102e-16  4.101751e-16  1.259337e-16 -1.961088e-16  1.110558e-15  1.146147e-15  0.000000e+00 -1.124013e-15
[129] -2.240372e-15  1.183696e-15  7.853410e-16 -8.166640e-16  2.211918e-16  3.578724e-16  3.203541e-18  8.414544e-16
[137]  0.000000e+00  4.299163e-16  0.000000e+00  3.558869e-17 -2.373008e-15  1.883190e-15 -2.337420e-15  0.000000e+00
[145]  9.330074e-17  1.977781e-16 -9.041401e-16  8.359987e-15  1.149833e-18  8.414274e-16  1.565482e-16  0.000000e+00
[153]  2.121390e-15  2.062992e-16  2.551096e-16 -7.268864e-16  1.294265e-14  0.000000e+00  0.000000e+00 -4.272341e-16
[161]  3.491955e-16  3.024710e-15 -1.129179e-15  3.746363e-16 -3.293207e-15 -2.204783e-15 -6.502917e-16 -9.112049e-16
[169]  2.868126e-15  1.899739e-14  5.085306e-17  0.000000e+00  6.117871e-16 -2.909207e-15 -8.498493e-15 -1.196316e-14
[177]  1.315773e-14  0.000000e+00  1.043835e-16 -2.258222e-15 -1.005260e-15  3.203541e-18  0.000000e+00 -1.167754e-17
[185] -8.389224e-16  1.247032e-15 -3.801849e-15  0.000000e+00  5.493600e-14  4.227009e-16  2.058324e-14  2.485160e-14
[193]  0.000000e+00  6.456092e-15  6.491681e-15 -8.756162e-16  7.339651e-15  4.718282e-16 -3.823871e-16  1.335051e-14
```