

# Visualization of Network and it's Node descriptive

Using the Teacher-Student network

```
library(igraph)
```

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

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

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

```
g4 <- graph( c('Susann', 'Jeanette', 'Harrison', 'Myron', 'Julie', 'Colten', 'Brandyn', 'Leland', 'Catherine',  
'Tracy', 'Bee', 'Maureen', 'Annika', 'Hans', 'Spenser', 'Angelo', 'Blanche', 'Stanford', 'Hope', 'Catherine',  
'Almira', 'Thomas', 'Henry', 'Ralph', 'Louvenia', 'German', 'Lura', 'Wilma', 'Lauretta', 'Maudie', 'Martha',  
'Henry', 'Lloyd', 'Mayra', 'Noelle', 'Fabian', 'Ira', 'Zenobia', 'Noelle', 'Natalie', 'Brooke', 'German',  
'Lauretta', 'Zenobia', 'Hallie', 'Braxton', 'Lorraine', 'Alicia', 'Allie', 'Jaylon', 'Myrna', 'Darrel', 'Lura',  
'Hermon', 'Wyatt', 'Raoul', 'Althea', 'Laurel', 'Leola', 'Darrel', 'Giles', 'Merritt', 'Angelo', 'Kendrick',  
'Travis', 'Henry', 'Owen', 'Almira', 'Michelle', 'Lou', 'Stephan', 'Leola', 'Wyatt', 'Allie', 'Eli',  
'Brandyn', 'Mayra', 'Chin', 'Clarence', 'Marlee', 'Glenn', 'Reid', 'Glenn', 'Jerrold', 'Dale', 'Helena',  
'Alvie', 'Elden', 'Chaim', 'Merritt', 'Augustine', 'Curtiss', 'Alvie', 'Allie', 'Pollie', 'Catherine', 'Angelita',  
'Glenn', 'Allie', 'Braden', 'Manford', 'Raoul', 'Dwight', 'Pollie', 'Zona', 'Reggie', 'Dominic', 'Amy',  
'Santos', 'Faron', 'Leslie', 'Etha', 'Maureen', 'Juanita', 'Gust', 'Noelle', 'Darrel', 'Darin', 'Faron',  
'Zona', 'Myron', 'Hans', 'German', 'Elden', 'Mayra', 'Merritt', 'Myron', 'Gerald', 'Andrea', 'German', 'Angelita',  
'Giles', 'Reggie', 'Wyatt', 'Alvie', 'Darrel', 'Jarrett', 'Newell', 'Brandyn', 'Eloisa', 'Santos', 'Lou',  
'Quintin', 'Zechariah', 'Leola', 'Anthony', 'Eliga', 'Gust', 'Obie', 'Obie', 'Brandyn', 'Brooke', 'Dominic',  
'Jacoby', 'Maureen', 'Hardie', 'Noelle', 'Braxton', 'Noelle', 'Leola', 'Marlee', 'Helena', 'Ira', 'Kermit',  
'Wilda', 'Eli', 'Chance', 'Hardie', 'Andrea', 'Johnnie', 'Lauretta', 'Tracy', 'Kathryn', 'Spenser', 'Lou',  
'Dana', 'Dominic', 'Rachelle', 'Glenn', 'Darrel', 'Deidra', 'Orpha', 'Hermon', 'Rosalind', 'Hans', 'Curtis',  
'Josue', 'Wyatt', 'Agatha', 'Wyatt', 'Chance', 'Glenn', 'Kendrick', 'Brooke', 'Hollie', 'Beverly', 'Katarina',  
'Josue', 'Leslie', 'Colten', 'Mayra', 'Darin', 'Hermon', 'Myron', 'Alicia', 'Leila', 'Kermit', 'Lamar', 'Dana',  
'Johnnie', 'Althea', 'Judson', 'Colten', 'Hope', 'Gust', 'Clarence', 'Leland', 'Matthew', 'Lorraine', 'Althea',  
'Colten', 'Jewel', 'Leila', 'Eli', 'Zenobia', 'German', 'Jaylon', 'Henry', 'Michelle', 'Johnie', 'Judson',  
'Johnnie', 'Leslie', 'Wyatt', 'Lou', 'Maureen', 'Jacoby', 'Noelle', 'Johnnie', 'Alvie', 'Leila', 'Myron',  
'Wilda', 'Brandyn', 'Kendrick', 'Gerald', 'Tyson', 'Jacoby', 'Ari', 'Theo', 'Harrison', 'Carmen', 'Leonard',  
'Braden', 'Desi', 'Zona', 'Maureen', 'Ralph', 'Thomas', 'Myron', 'Austin', 'Leola', 'Lloyd', 'Quintin', 'Lorraine',  
'Glenn', 'Merritt', 'Janet', 'Myron', 'Alicia', 'Maureen', 'Leslie', 'Carla', 'Vicky', 'Harley', 'Leslie',  
'Hannah', 'Gust', 'Andrea', 'Giles', 'Wilma', 'Henry', 'Hermon', 'Stefani', 'Henry', 'Harley', 'Noelle',  
'Kermit', 'Laurel', 'Hermon', 'Sebastian', 'Andrea', 'Eliga', 'Sigmund', 'Darrel', 'Noelle', 'Urban',  
'Almira', 'Noelle', 'Dwight', 'Beverly', 'Wyatt', 'Juanita', 'Reid', 'Kermit', 'Myrna', 'Pollie', 'Hope',  
'Leola', 'Leslie', 'Jacoby', 'Pollie', 'Tiffany', 'Gust', 'Leland', 'Eliga', 'Lamar', 'Ira', 'Dale', 'Noelle',  
'Jarrett', 'Zenobia', 'Orpha', 'Glenn', 'Amy', 'Hermon', 'Myrna', 'Brandyn', 'Nell', 'Leslie', 'Edd', 'Lura',  
'Kendrick', 'Obie', 'Augustine', 'Zona', 'Glenn', 'Dominic', 'Jennifer', 'Rachelle', 'Faron', 'Darrel',  
'Pollie', 'Almira', 'Glenn', 'Wilma', 'Angus', 'Leila', 'Sherri'))
```

```
## Warning in matrix(edges, ncol = 2, byrow = TRUE): data length [349] is not a  
## sub-multiple or multiple of the number of rows [175]
```

```
V(g4)$name
```



```
edge_density(g4, loops=F)
```

```
## [1] 0.008266415
```

## 2. Finding the density of a graph- For directed graph

```
ecount(g4) / (vcount(g4) * (vcount(g4) - 1))
```

```
## [1] 0.008266415
```

Result: Density i.e. the proportion of present edges from all possible edges in the network was found.

## 3. Finding Reciprocity

```
reciprocity(g4)
```

```
## [1] 0
```

```
dyad_census(g4) # Mutual, asymmetric, and null node pairs
```

```
## $mut
## [1] 0
##
## $asym
## [1] 174
##
## $null
## [1] 10411
```

```
2*dyad_census(g4)$mut/ecount(g4) # Calculating reciprocity
```

```
## [1] 0
```

Result: The proportion of reciprocated ties (for a directed network) was found

## 4. Finding Transitivity

```
transitivity(g4, type="global") # g4 is treated as an undirected network
```

```
## [1] 0.03267974
```

```
transitivity(as.undirected(g4, mode="collapse")) # same as above
```

```
## [1] 0.03267974
```

```
transitivity(g4, type="local")
```

```
## [1] 0.00000000      NaN 0.00000000 0.04761905      NaN 0.00000000
## [7] 0.06666667 0.00000000 0.33333333 0.00000000      NaN 0.00000000
## [13]      NaN 0.00000000 0.00000000 0.00000000      NaN      NaN
## [19] 0.33333333 0.00000000 0.00000000 0.00000000 0.00000000      NaN
## [25] 0.00000000 0.00000000 0.00000000 0.00000000      NaN      NaN
## [31] 0.00000000 0.00000000 0.02222222      NaN 0.33333333 0.00000000
## [37]      NaN 0.00000000      NaN 0.00000000 0.00000000 0.33333333
## [43] 0.00000000 0.00000000 0.00000000 0.04761905 0.00000000 0.00000000
## [49] 0.00000000 0.00000000 0.00000000 0.06666667 0.00000000 0.00000000
## [55] 0.00000000      NaN      NaN 0.00000000 0.00000000      NaN
## [61] 0.33333333      NaN 0.00000000 0.00000000 0.00000000 0.00000000
## [67]      NaN 0.00000000 0.00000000 0.00000000 0.00000000      NaN
## [73] 0.00000000      NaN 0.10000000 0.00000000 0.00000000      NaN
## [79] 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000 0.00000000
## [85] 0.00000000 0.00000000      NaN 0.00000000 0.00000000 0.00000000
## [91] 0.00000000 0.00000000 0.00000000      NaN      NaN 0.00000000
## [97]      NaN      NaN 0.00000000 0.00000000 0.00000000 0.00000000
## [103] 0.16666667 1.00000000 0.00000000 0.00000000      NaN 0.00000000
## [109] 0.00000000      NaN 0.00000000      NaN      NaN 0.00000000
## [115]      NaN      NaN 0.00000000      NaN 0.16666667 1.00000000
## [121] 0.00000000      NaN      NaN      NaN      NaN      NaN
## [127]      NaN      NaN      NaN      NaN      NaN      NaN
## [133]      NaN      NaN 0.00000000      NaN      NaN      NaN
## [139]      NaN      NaN      NaN      NaN      NaN      NaN
## [145]      NaN      NaN
```

```
triad_census(g4) # for directed networks
```

```
## [1] 483478 24153 0 95 109 240 0 0 2 3
## [11] 0 0 0 0 0 0
```

Result: Global transitivity i.e. the ratio of triangles (direction disregarded) to connected triples and local transitivity i.e. ratio of triangles to connected triples each vertex is part of was found.

## 5.Finding Diameter

```
diameter(g4, directed=F, weights=NA)
```

```
## [1] 12
```

```
diameter(g4, directed=F)
```

```
## [1] 7.066154
```

```
diam <- get_diameter(g4, directed=T)
diam
```

```
## + 16/146 vertices, named, from 45a4802:
## [1] Michelle Lou      Dana      Johnnie  Alvie      Darrel    Noelle    Kermit
## [9] Myrna      Brandyn  Leland   Eliga      Gust      Clarence  Marlee    Helena
```

```
class(diam)
```

```
## [1] "igraph.vs"
```

```
as.vector(diam)
```

```
## [1] 58 59 108 106 70 46 33 103 45 7 8 99 89 63 64 69
```

```

vcol <- rep("gray40", vcount(g4))

vcol[diam] <- "gold"

ecol <- rep("gray80", ecount(g4))

ecol[E(g4, path=diam)] <- "orange"

E(g4, path=diam) #finds edges along a path, here 'diam'

```

```

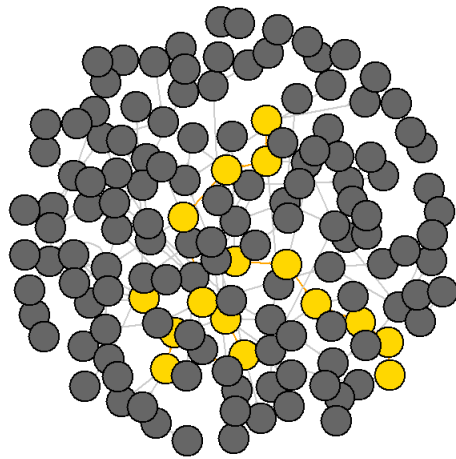
## + 15/175 edges from 45a4802 (vertex names):
## [1] Michelle->Lou      Lou      ->Dana    Dana     ->Johnnie  Johnnie  ->Alvie
## [5] Alvie    ->Darrel    Darrel   ->Noelle  Noelle   ->Kermit   Kermit   ->Myrna
## [9] Myrna    ->Brandyn  Brandyn  ->Leland  Leland   ->Eliga    Eliga    ->Gust
## [13] Gust     ->Clarence  Clarence->Marlee  Marlee   ->Helena

```

```

plot(g4, vertex.color=vcol, edge.color=ecol, edge.arrow.size=.05, vertex.label=NA)

```



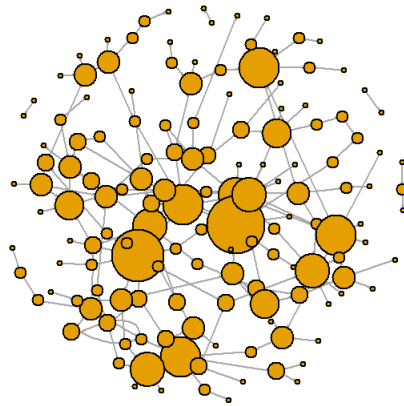
Result: A network diameter, the longest geodesic distance (length of the shortest path between two nodes) in the network was found. In igraph, `diameter()` returns the distance, while `get_diameter()` returns the nodes along the first found path of that distance. Edge weights are used by default, unless set to NA. A graph was also plotted with colored nodes along the diameter.

## 6. Finding Node Degrees

```

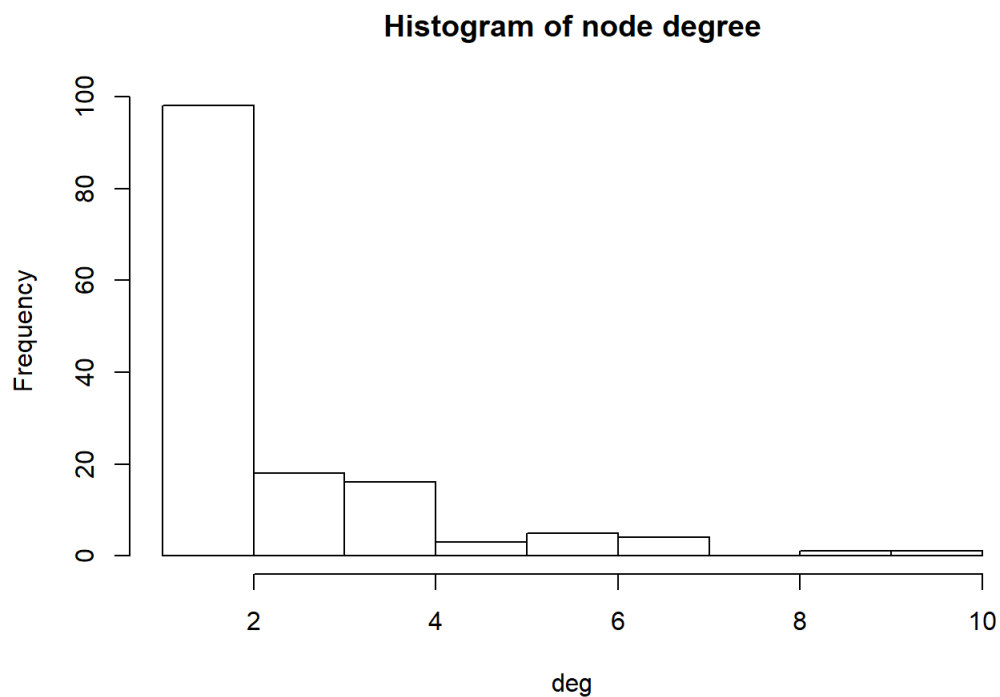
deg <- degree(g4, mode="all")
plot(g4, vertex.size=deg*3, edge.arrow.size=.05, vertex.label=NA)

```



## 7. Visualizing the Degree histogram

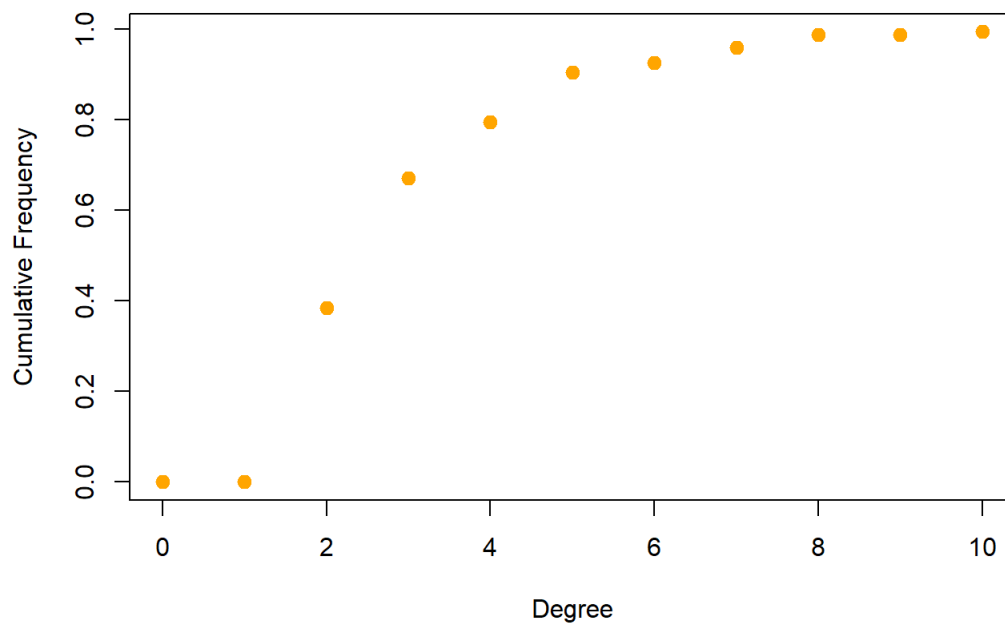
```
hist(deg, main="Histogram of node degree")
```



Result: The node degrees were found and a histogram was plotted.

## 8. Finding degree distribution

```
deg.dist <- degree_distribution(g4, cumulative=T, mode="all")
plot( x=0:max(deg), y=1-deg.dist, pch=19, cex=1.2, col="orange",
      xlab="Degree", ylab="Cumulative Frequency")
```



Result: The degree distribution vs cumulative frequency was plotted

Centrality & centralization 9. Finding Degree centrality

```
degree(g4, mode="in")
```

```
##      Susann  Jeanette  Harrison    Myron    Julie    Colten  Brandyn  Leland
##      1        1        0        4        0        2        3        1
## Catherine    Tracy    Bee  Maureen  Annika    Hans  Spencer  Angelo
##      2        2        0        2        0        2        1        1
## Blanche  Stanford    Hope  Almira  Thomas    Henry    Ralph  Louvenia
##      0        1        2        3        1        4        2        0
## German    Lura    Wilma  Lauretta  Maudie  Martha    Loyd    Mayra
##      4        1        2        0        1        0        0        1
## Noelle    Fabian    Ira  Zenobia  Natalie  Brooke  Hallie  Braxton
##      4        1        1        3        1        2        0        2
## Lorraine  Alicia  Allie  Jaylon  Myrna  Darrel  Hermon  Wyatt
##      0        2        2        1        1        5        3        5
## Raoul    Althea  Laurel  Leola  Giles  Merritt  Kendrick  Travis
##      2        1        1        3        2        3        1        0
## Owen    Michelle    Lou  Stephan    Eli    Chin  Clarence  Marlee
##      0        0        2        0        2        1        1        1
## Glenn    Reid  Jerrold    Dale  Helena  Alvie    Elden  Chaim
##      4        2        1        0        2        1        2        0
## Augustine  Curtiss  Pollie  Angelita  Braden  Manford  Dwight    Zona
##      0        1        2        0        2        0        1        3
## Reggie  Dominic    Amy  Santos  Faron  Leslie    Etha  Juanita
##      1        1        1        0        1        4        1        1
## Gust    Darin  Gerald  Andrea  Jarrett  Newell  Eloisa  Quintin
##      3        2        2        1        0        1        1        1
## Zechariah  Anthony  Eliga  Obie  Jacoby  Hardie  Kermit  Wilda
##      1        1        1        2        2        2        2        0
## Chance  Johnnie  Kathryn  Dana  Rachelle  Deidra  Orpha  Rosalind
##      0        3        0        1        2        0        1        1
## Curtis    Josue  Agatha  Hollie  Beverly  Katarina  Leila  Lamar
##      1        1        0        0        1        0        2        1
## Judson  Matthew  Jewel  Johnnie  Tyson    Ari    Theo  Carmen
##      1        1        1        1        0        0        1        1
## Leonard    Desi  Austin  Janet  Carla  Vicky  Harley  Hannah
##      0        0        0        1        0        1        1        0
## Stefani  Sebastian  Sigmund  Urban  Tiffany    Nell    Edd  Jennifer
##      1        0        1        0        0        0        0        0
## Angus    Sherri
##      0        0
```

```
centr_degree(g4, mode="in", normalized=T)
```

```
## $res
##   [1] 1 1 0 4 0 2 3 1 2 2 0 2 0 2 1 1 0 1 2 3 1 4 2 0 4 1 2 0 1 0 0 1 4 1 1 3 1
##   [38] 2 0 2 0 2 2 1 1 5 3 5 2 1 1 3 2 3 1 0 0 0 2 0 2 1 1 1 4 2 1 0 2 1 2 0 0 1
##   [75] 2 0 2 0 1 3 1 1 1 0 1 4 1 1 3 2 2 1 0 1 1 1 1 1 1 2 2 2 2 0 0 3 0 1 2 0 1
##  [112] 1 1 1 0 0 1 0 2 1 1 1 1 1 0 0 1 1 0 0 0 1 0 1 1 0 1 0 1 0 0 0 0 0 0 0
##
## $centralization
## [1] 0.02621634
##
## $theoretical_max
## [1] 21170
```

## 10. Finding Closeness centrality

```
closeness(g4, mode="all", weights=NA)
```

```
## Warning in closeness(g4, mode = "all", weights = NA): At centrality.c:
## 2784 :closeness centrality is not well-defined for disconnected graphs
```



##	Susann	Jeanette	Harrison	Myron	Julie	Colten
##	4.789272e-05	4.789043e-05	4.701457e-04	5.015045e-04	4.784689e-04	5.115090e-04
##	Brandyn	Leland	Catherine	Tracy	Bee	Maureen
##	5.246590e-04	4.970179e-04	4.982561e-04	4.805382e-04	4.821601e-04	5.157298e-04
##	Annika	Hans	Spenser	Angelo	Blanche	Stanford
##	4.424779e-04	4.705882e-04	4.364906e-04	4.633920e-04	4.756243e-05	4.756243e-05
##	Hope	Almira	Thomas	Henry	Ralph	Louvenia
##	5.053057e-04	4.987531e-04	4.901961e-04	5.133470e-04	4.980080e-04	4.816956e-04
##	German	Lura	Wilma	Lauretta	Maudie	Martha
##	5.151984e-04	5.070994e-04	5.285412e-04	4.775549e-04	4.486317e-04	4.800768e-04
##	Lloyd	Mayra	Noelle	Fabian	Ira	Zenobia
##	4.697041e-04	5.005005e-04	5.515720e-04	5.133470e-04	5.032713e-04	5.002501e-04
##	Natalie	Brooke	Hallie	Braxton	Lorraine	Alicia
##	5.133470e-04	5.117707e-04	4.805382e-04	5.138746e-04	5.260389e-04	5.091650e-04
##	Allie	Jaylon	Myrna	Darrel	Hermon	Wyatt
##	5.238345e-04	5.040323e-04	5.405405e-04	5.640158e-04	5.035247e-04	5.146680e-04
##	Raoul	Althea	Laurel	Leola	Giles	Merritt
##	4.816956e-04	5.047956e-04	4.885198e-04	5.485464e-04	5.099439e-04	4.889976e-04
##	Kendrick	Travis	Owen	Michelle	Lou	Stephan
##	4.933399e-04	4.800768e-04	4.672897e-04	4.703669e-04	5.017561e-04	5.107252e-04
##	Eli	Chin	Clarance	Marlee	Glenn	Reid
##	5.022602e-04	4.688233e-04	4.878049e-04	4.585053e-04	5.509642e-04	5.202914e-04
##	Jerrold	Dale	Helena	Alvie	Elden	Chaim
##	5.128205e-04	5.144033e-04	4.819277e-04	5.437738e-04	5.211047e-04	4.587156e-04
##	Augustine	Curtiss	Pollie	Angelita	Braden	Manford
##	4.739336e-04	4.454343e-04	5.184033e-04	5.232862e-04	4.897160e-04	4.522840e-04
##	Dwight	Zona	Reggie	Dominic	Amy	Santos
##	5.232862e-04	5.058169e-04	4.926108e-04	5.324814e-04	5.091650e-04	5.050505e-04
##	Faron	Leslie	Etha	Juanita	Gust	Darin
##	5.324814e-04	5.347594e-04	4.987531e-04	5.027652e-04	5.211047e-04	5.288207e-04
##	Gerald	Andrea	Jarrett	Newell	Eloisa	Quintin
##	4.854369e-04	5.144033e-04	4.690432e-04	4.411116e-04	4.899559e-04	4.420866e-04
##	Zechariah	Anthony	Eliga	Obie	Jacoby	Hardie
##	4.171882e-04	5.107252e-04	4.995005e-04	4.625347e-04	5.336179e-04	5.027652e-04
##	Kermit	Wilda	Chance	Johnnie	Kathryn	Dana
##	5.288207e-04	4.955401e-04	5.202914e-04	5.246590e-04	4.122012e-04	5.010020e-04
##	Rachelle	Deidra	Orpha	Rosalind	Curtis	Josue
##	4.972650e-04	4.800768e-04	5.133470e-04	4.714757e-04	4.424779e-04	4.816956e-04
##	Agatha	Hollie	Beverly	Katarina	Leila	Lamar
##	4.812320e-04	4.522840e-04	4.816956e-04	4.522840e-04	4.955401e-04	4.967710e-04
##	Judson	Matthew	Jewel	Johnnie	Tyson	Ari
##	5.030181e-04	4.657662e-04	4.784689e-04	4.422822e-04	4.977601e-04	4.756243e-05
##	Theo	Carmen	Leonard	Desi	Austin	Janet
##	4.756243e-05	4.420866e-04	4.593477e-04	4.734848e-04	5.107252e-04	4.587156e-04
##	Carla	Vicky	Harley	Hannah	Stefani	Sebastian
##	4.756243e-05	4.756243e-05	5.120328e-04	4.868549e-04	4.714757e-04	4.810005e-04
##	Sigmund	Urban	Tiffany	Nell	Edd	Jennifer
##	4.679457e-04	4.672897e-04	4.868549e-04	4.987531e-04	4.746084e-04	4.659832e-04
##	Angus	Sherri				
##	4.644682e-04	4.789043e-05				

```
centr_clo(g4, mode="all", normalized=T)
```

```
## Warning in centr_clo(g4, mode = "all", normalized = T): At centrality.c:
## 2784 :closeness centrality is not well-defined for disconnected graphs
```

```
## $res
## [1] 0.006944444 0.006944112 0.068171133 0.072718154 0.069377990 0.074168798
## [7] 0.076075551 0.072067594 0.072247135 0.069678039 0.069913211 0.074780815
## [13] 0.064159292 0.068235294 0.063291139 0.067191844 0.006896552 0.006896552
## [19] 0.073269328 0.072319202 0.071078431 0.074435318 0.072211155 0.069845857
## [25] 0.074703761 0.073529412 0.076638478 0.069245463 0.065051593 0.069611138
## [31] 0.068107093 0.072572573 0.079977937 0.074435318 0.072974333 0.072536268
## [37] 0.074435318 0.074206755 0.069678039 0.074511819 0.076275644 0.073828921
## [43] 0.075955998 0.073084677 0.078378378 0.081782290 0.073011078 0.074626866
## [49] 0.069845857 0.073195356 0.070835369 0.079539221 0.073941866 0.070904645
## [55] 0.071534287 0.069611138 0.067757009 0.068203198 0.072754641 0.074055158
## [61] 0.072827725 0.067979372 0.070731707 0.066483265 0.079889807 0.075442248
## [67] 0.074358974 0.074588477 0.069879518 0.078847200 0.075560188 0.066513761
## [73] 0.068720379 0.064587973 0.075168481 0.075876504 0.071008815 0.065581185
## [79] 0.075876504 0.073343450 0.071428571 0.077209798 0.073828921 0.073232323
## [85] 0.077209798 0.077540107 0.072319202 0.072900955 0.075560188 0.076679006
## [91] 0.070388350 0.074588477 0.068011257 0.063961182 0.071043606 0.064102564
## [97] 0.060492282 0.074055158 0.072427572 0.067067530 0.077374600 0.072900955
## [103] 0.076679006 0.071853320 0.075442248 0.076075551 0.059769167 0.072645291
## [109] 0.072103431 0.069611138 0.074435318 0.068363979 0.064159292 0.069845857
## [115] 0.069778633 0.065581185 0.069845857 0.065581185 0.071853320 0.072031793
## [121] 0.072937626 0.067536097 0.069377990 0.064130916 0.072175212 0.006896552
## [127] 0.006896552 0.064102564 0.066605420 0.068655303 0.074055158 0.066513761
## [133] 0.006896552 0.006896552 0.074244752 0.070593963 0.068363979 0.069745070
## [139] 0.067852129 0.067757009 0.070593963 0.072319202 0.068818225 0.067567568
## [145] 0.067347887 0.006944112
##
## $centralization
## [1] 0.02888468
##
## $theoretical_max
## [1] 72.24913
```

## 11. Finding Eigenvector centrality

```
eigen_centrality(g4, directed=T, weights=NA)
```

```
## $vector
##      Susann      Jeanette      Harrison      Myron      Julie      Colten
## 0.000000e+00 0.000000e+00 2.403304e-17 2.718716e-01 2.403304e-17 3.787944e-01
##      Brandyn      Leland      Catherine      Tracy      Bee      Maureen
## 5.953273e-01 4.298795e-01 7.573553e-01 5.468782e-01 2.403304e-17 0.000000e+00
##      Annika      Hans      Spenser      Angelo      Blanche      Stanford
## 2.403304e-17 1.963156e-01 0.000000e+00 0.000000e+00 2.403304e-17 0.000000e+00
##      Hope      Almira      Thomas      Henry      Ralph      Louvenia
## 5.986209e-01 3.250975e-01 2.347494e-01 1.426187e-01 1.029835e-01 2.403304e-17
##      German      Lura      Wilma      Lauretta      Maudie      Martha
## 5.822831e-01 0.000000e+00 0.000000e+00 2.403304e-17 0.000000e+00 2.403304e-17
##      Loyd      Mayra      Noelle      Fabian      Ira      Zenobia
## 2.403304e-17 0.000000e+00 8.634570e-01 6.234931e-01 5.214131e-01 3.765069e-01
##      Natalie      Brooke      Hallie      Braxton      Lorraine      Alicia
## 6.234931e-01 4.298795e-01 2.403304e-17 6.234931e-01 2.403304e-17 1.963156e-01
##      Allie      Jaylon      Myrna      Darrel      Hermon      Wyatt
## 2.735234e-01 1.975084e-01 7.220894e-01 9.716309e-01 0.000000e+00 3.787944e-01
##      Raoul      Althea      Laurel      Leola      Giles      Merritt
## 2.735234e-01 0.000000e+00 0.000000e+00 6.234931e-01 0.000000e+00 0.000000e+00
##      Kendrick      Travis      Owen      Michelle      Lou      Stephan
## 0.000000e+00 2.403304e-17 2.403304e-17 2.403304e-17 0.000000e+00 2.403304e-17
##      Eli      Chin      Clarence      Marlee      Glenn      Reid
## 1.023615e-01 0.000000e+00 1.618526e-01 1.168720e-01 0.000000e+00 0.000000e+00
##      Jerrold      Dale      Helena      Alvie      Elden      Chaim
## 0.000000e+00 2.403304e-17 8.439207e-02 0.000000e+00 4.204604e-01 2.403304e-17
##      Augustine      Curtiss      Pollie      Angelita      Braden      Manford
## 2.403304e-17 0.000000e+00 4.502178e-01 2.403304e-17 1.975084e-01 2.403304e-17
##      Dwight      Zona      Reggie      Dominic      Amy      Santos
## 6.234931e-01 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00 2.403304e-17
##      Faron      Leslie      Etha      Juanita      Gust      Darin
## 0.000000e+00 5.245810e-01 3.787944e-01 0.000000e+00 2.241448e-01 7.016044e-01
##      Gerald      Andrea      Jarrett      Newell      Eloisa      Quintin
## 1.963156e-01 0.000000e+00 2.403304e-17 0.000000e+00 4.298795e-01 0.000000e+00
##      Zechariah      Anthony      Eliga      Obie      Jacoby      Hardie
```

```

## 0.000000e+00 4.502178e-01 3.104114e-01 0.000000e+00 0.000000e+00 0.000000e+00
## Kermit Wilda Chance Johnnie Kathryn Dana
## 1.000000e+00 2.403304e-17 2.403304e-17 0.000000e+00 2.403304e-17 0.000000e+00
## Rachelle Deidra Orpha Rosalind Curtis Josue
## 0.000000e+00 2.403304e-17 0.000000e+00 0.000000e+00 1.417574e-01 0.000000e+00
## Agatha Hollie Beverly Katarina Leila Lamar
## 2.403304e-17 2.403304e-17 0.000000e+00 2.403304e-17 1.417574e-01 7.220894e-01
## Judson Matthew Jewel Johnnie Tyson Ari
## 0.000000e+00 3.104114e-01 2.735234e-01 0.000000e+00 2.403304e-17 2.403304e-17
## Theo Carmen Leonard Desi Austin Janet
## 0.000000e+00 0.000000e+00 2.403304e-17 2.403304e-17 2.403304e-17 0.000000e+00
## Carla Vicky Harley Hannah Stefani Sebastian
## 2.403304e-17 0.000000e+00 1.029835e-01 2.403304e-17 0.000000e+00 2.403304e-17
## Sigmund Urban Tiffany Nell Edd Jennifer
## 2.241448e-01 2.403304e-17 2.403304e-17 2.403304e-17 2.403304e-17 2.403304e-17
## Angus Sherri
## 2.403304e-17 2.403304e-17
##
## $value
## [1] 1.38487
##
## $options
## $options$bm
## [1] "I"
##
## $options$n
## [1] 146
##
## $options$which
## [1] "LR"
##
## $options$nev
## [1] 1
##
## $options$tol
## [1] 0
##
## $options$ncv
## [1] 0
##
## $options$ldev
## [1] 0
##
## $options$ishift
## [1] 1
##
## $options$maxiter
## [1] 1000
##
## $options$nb
## [1] 1
##
## $options$mode
## [1] 1
##
## $options$start
## [1] 1
##
## $options$sigma
## [1] 0
##
## $options$sigmai
## [1] 0
##
## $options$info
## [1] 0
##
## $options$iter
## [1] 5
##
## $options$conv
## [1] 1
##

```

```
## $options$numop
## [1] 58
##
## $options$numopb
## [1] 0
##
## $options$numreo
## [1] 24
```

```
centr_eigen(g4, directed=T, normalized=T)
```

```
## $vector
## [1] 0.000000e+00 0.000000e+00 0.000000e+00 2.718716e-01 0.000000e+00
## [6] 3.787944e-01 5.953273e-01 4.298795e-01 7.573553e-01 5.468782e-01
## [11] 0.000000e+00 1.290774e-16 0.000000e+00 1.963156e-01 0.000000e+00
## [16] 1.644882e-17 0.000000e+00 0.000000e+00 5.986209e-01 3.250975e-01
## [21] 2.347494e-01 1.426187e-01 1.029835e-01 0.000000e+00 5.822831e-01
## [26] 1.396862e-17 3.572454e-16 0.000000e+00 0.000000e+00 0.000000e+00
## [31] 0.000000e+00 0.000000e+00 8.634570e-01 6.234931e-01 5.214131e-01
## [36] 3.765069e-01 6.234931e-01 4.298795e-01 0.000000e+00 6.234931e-01
## [41] 0.000000e+00 1.963156e-01 2.735234e-01 1.975084e-01 7.220894e-01
## [46] 9.716309e-01 4.044745e-16 3.787944e-01 2.735234e-01 5.105029e-20
## [51] 0.000000e+00 6.234931e-01 8.370350e-17 1.285601e-16 4.319572e-17
## [56] 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
## [61] 1.023615e-01 5.317325e-18 1.618526e-01 1.168720e-01 6.217226e-17
## [66] 5.259037e-16 3.664746e-16 0.000000e+00 8.439207e-02 3.792494e-16
## [71] 4.204604e-01 0.000000e+00 0.000000e+00 4.183173e-18 4.502178e-01
## [76] 0.000000e+00 1.975084e-01 0.000000e+00 6.234931e-01 1.671994e-17
## [81] 1.662641e-16 2.110827e-16 2.744507e-16 0.000000e+00 0.000000e+00
## [86] 5.245810e-01 3.787944e-01 1.494382e-16 2.241448e-01 7.016044e-01
## [91] 1.963156e-01 1.585067e-17 0.000000e+00 0.000000e+00 4.298795e-01
## [96] 1.255000e-17 4.660628e-17 4.502178e-01 3.104114e-01 1.299551e-15
## [101] 3.032980e-16 2.108926e-16 1.000000e+00 0.000000e+00 0.000000e+00
## [106] 1.797581e-16 0.000000e+00 5.963123e-17 3.154508e-16 0.000000e+00
## [111] 6.864657e-19 6.020268e-16 1.417574e-01 0.000000e+00 0.000000e+00
## [116] 0.000000e+00 0.000000e+00 0.000000e+00 1.417574e-01 7.220894e-01
## [121] 1.789918e-17 3.104114e-01 2.735234e-01 1.710860e-17 0.000000e+00
## [126] 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
## [131] 0.000000e+00 3.373790e-16 0.000000e+00 8.887438e-18 1.029835e-01
## [136] 0.000000e+00 6.302328e-16 0.000000e+00 2.241448e-01 0.000000e+00
## [141] 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
## [146] 0.000000e+00
##
## $value
## [1] 1.38487
##
## $options
## $options$bmat
## [1] "I"
##
## $options$n
## [1] 146
##
## $options$which
## [1] "LR"
##
## $options$nev
## [1] 1
##
## $options$tol
## [1] 0
##
## $options$ncv
## [1] 0
##
## $options$lsv
## [1] 0
##
## $options$ishift
## [1] 1
##
```

```
## $options$maxiter
## [1] 1000
##
## $options$nb
## [1] 1
##
## $options$mode
## [1] 1
##
## $options$start
## [1] 1
##
## $options$sigma
## [1] 0
##
## $options$sigma_i
## [1] 0
##
## $options$info
## [1] 0
##
## $options$iter
## [1] 5
##
## $options$nconv
## [1] 1
##
## $options$numop
## [1] 58
##
## $options$numopb
## [1] 0
##
## $options$numreo
## [1] 24
##
##
## $centralization
## [1] 0.8610265
##
## $theoretical_max
## [1] 145
```

## 12. Finding Betweenness centrality

```
betweenness(g4, directed=T, weights=NA)
```

##	Susann	Jeanette	Harrison	Myron	Julie	Colten	Brandyn
##	1.00000	0.00000	0.00000	808.00000	0.00000	165.00000	1105.50000
##	Leland	Catherine	Tracy	Bee	Maureen	Annika	Hans
##	929.00000	78.00000	0.00000	0.00000	61.66667	0.00000	55.00000
##	Spenser	Angelo	Blanche	Stanford	Hope	Almira	Thomas
##	7.00000	12.00000	0.00000	0.00000	61.00000	451.00000	449.00000
##	Henry	Ralph	Louvenia	German	Lura	Wilma	Lauretta
##	317.50000	0.00000	0.00000	54.00000	56.00000	73.50000	0.00000
##	Maudie	Martha	Loyd	Mayra	Noelle	Fabian	Ira
##	0.00000	0.00000	0.00000	4.00000	1794.50000	0.00000	126.50000
##	Zenobia	Natalie	Brooke	Hallie	Braxton	Lorraine	Alicia
##	32.50000	0.00000	74.50000	0.00000	0.00000	0.00000	663.00000
##	Allie	Jaylon	Myrna	Darrel	Hermion	Wyatt	Raoul
##	394.00000	259.00000	451.50000	871.50000	263.00000	477.33333	0.00000
##	Althea	Laurel	Leola	Giles	Merritt	Kendrick	Travis
##	11.00000	25.00000	666.50000	6.00000	7.00000	15.00000	0.00000
##	Owen	Michelle	Lou	Stephan	Eli	Chin	Clarence
##	0.00000	0.00000	78.33333	0.00000	694.00000	0.00000	107.00000
##	Marlee	Glenn	Reid	Jerrold	Dale	Helena	Alvie
##	54.00000	284.00000	0.00000	0.00000	0.00000	0.00000	374.66667
##	Elden	Chaim	Augustine	Curtiss	Pollie	Angelita	Braden
##	0.00000	0.00000	0.00000	0.00000	488.00000	0.00000	0.00000
##	Manford	Dwight	Zona	Reggie	Dominic	Amy	Santos
##	0.00000	422.00000	44.66667	55.66667	104.00000	60.00000	0.00000
##	Faron	Leslie	Etha	Juanita	Gust	Darin	Gerald
##	41.66667	702.66667	0.00000	5.00000	921.00000	0.00000	0.00000
##	Andrea	Jarrett	Newell	Eloisa	Quintin	Zechariah	Anthony
##	57.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000
##	Eliga	Obie	Jacoby	Hardie	Kermit	Wilda	Chance
##	873.00000	0.00000	133.00000	0.00000	635.00000	0.00000	0.00000
##	Johnnie	Kathryn	Dana	Rachelle	Deidra	Orpha	Rosalind
##	331.66667	0.00000	87.66667	0.00000	0.00000	63.00000	0.00000
##	Curtis	Josue	Agatha	Hollie	Beverly	Katarina	Leila
##	0.00000	15.00000	0.00000	0.00000	15.00000	0.00000	713.00000
##	Lamar	Judson	Matthew	Jewel	Johnie	Tyson	Ari
##	128.50000	41.00000	0.00000	0.00000	0.00000	0.00000	0.00000
##	Theo	Carmen	Leonard	Desi	Austin	Janet	Carla
##	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
##	Vicky	Harley	Hannah	Stefani	Sebastian	Sigmund	Urban
##	0.00000	187.50000	0.00000	0.00000	0.00000	0.00000	0.00000
##	Tiffany	Nell	Edd	Jennifer	Angus	Sherri	
##	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	

```
edge_betweenness(g4, directed=T, weights=NA)
```

##	[1]	2.00000	52.00000	5.00000	982.00000	79.00000	19.00000	2.00000
##	[8]	14.00000	1.00000	63.00000	502.00000	70.00000	2.00000	32.00000
##	[15]	1.00000	15.00000	5.00000	54.00000	82.50000	54.00000	76.50000
##	[22]	3.00000	1.00000	19.00000	333.00000	140.00000	80.00000	75.00000
##	[29]	27.00000	163.00000	8.00000	18.00000	15.00000	52.00000	60.00000
##	[36]	52.00000	416.33333	745.00000	2.00000	109.00000	6.00000	6.00000
##	[43]	1.00000	9.00000	2.00000	1.00000	51.66667	93.00000	63.00000
##	[50]	75.00000	1.00000	473.00000	60.66667	67.00000	42.66667	75.00000
##	[57]	10.00000	811.00000	54.00000	14.66667	108.00000	55.00000	4.00000
##	[64]	54.00000	4.00000	3.00000	70.66667	366.00000	1.00000	54.00000
##	[71]	20.33333	2.00000	54.00000	870.00000	0.00000	120.50000	88.00000
##	[78]	5.00000	54.00000	615.50000	55.00000	95.00000	1.00000	1.00000
##	[85]	104.00000	1.00000	8.00000	90.66667	7.00000	174.50000	64.00000
##	[92]	13.00000	56.00000	30.00000	15.00000	63.00000	12.00000	16.00000
##	[99]	16.00000	236.00000	2.00000	291.00000	714.00000	181.50000	141.66667
##	[106]	43.00000	92.00000	161.00000	54.00000	12.00000	77.00000	746.00000
##	[113]	34.50000	273.00000	1.00000	95.00000	405.66667	46.66667	117.00000
##	[120]	384.66667	18.00000	51.00000	4.00000	53.00000	1.00000	1.00000
##	[127]	1.00000	17.00000	5.00000	500.00000	52.00000	2.00000	37.00000
##	[134]	8.00000	697.00000	59.66667	1.00000	201.50000	52.00000	6.00000
##	[141]	88.50000	13.00000	261.50000	593.00000	80.00000	58.00000	54.00000
##	[148]	868.50000	52.00000	475.00000	30.00000	6.00000	504.50000	46.00000
##	[155]	500.50000	68.00000	52.00000	926.00000	179.50000	51.00000	3.00000
##	[162]	126.00000	115.00000	362.50000	15.00000	57.00000	4.00000	17.00000
##	[169]	110.00000	1.00000	81.00000	400.00000	49.50000	52.00000	2.00000

```
centr_betw(g4, directed=T, normalized=T)
```

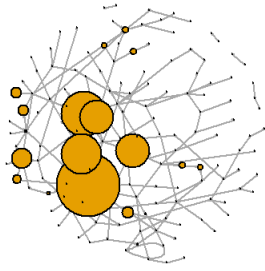
```
## $res
## [1] 1.00000 0.00000 0.00000 808.00000 0.00000 165.00000
## [7] 1105.50000 929.00000 78.00000 0.00000 0.00000 61.66667
## [13] 0.00000 55.00000 7.00000 12.00000 0.00000 0.00000
## [19] 61.00000 451.00000 449.00000 317.50000 0.00000 0.00000
## [25] 54.00000 56.00000 73.50000 0.00000 0.00000 0.00000
## [31] 0.00000 4.00000 1794.50000 0.00000 126.50000 32.50000
## [37] 0.00000 74.50000 0.00000 0.00000 0.00000 663.00000
## [43] 394.00000 259.00000 451.50000 871.50000 263.00000 477.33333
## [49] 0.00000 11.00000 25.00000 666.50000 6.00000 7.00000
## [55] 15.00000 0.00000 0.00000 0.00000 78.33333 0.00000
## [61] 694.00000 0.00000 107.00000 54.00000 284.00000 0.00000
## [67] 0.00000 0.00000 0.00000 374.66667 0.00000 0.00000
## [73] 0.00000 0.00000 488.00000 0.00000 0.00000 0.00000
## [79] 422.00000 44.66667 55.66667 104.00000 60.00000 0.00000
## [85] 41.66667 702.66667 0.00000 5.00000 921.00000 0.00000
## [91] 0.00000 57.00000 0.00000 0.00000 0.00000 1.00000
## [97] 0.00000 0.00000 873.00000 0.00000 133.00000 0.00000
## [103] 635.00000 0.00000 0.00000 331.66667 0.00000 87.66667
## [109] 0.00000 0.00000 63.00000 0.00000 0.00000 15.00000
## [115] 0.00000 0.00000 15.00000 0.00000 713.00000 128.50000
## [121] 41.00000 0.00000 0.00000 0.00000 0.00000 0.00000
## [127] 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
## [133] 0.00000 0.00000 187.50000 0.00000 0.00000 0.00000
## [139] 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
## [145] 0.00000 0.00000
##
## $centralization
## [1] 0.08041122
##
## $theoretical_max
## [1] 3027600
```

Result: 1. Degree i.e. number of ties was found 2. Closeness i.e. centrality based on distance to others in the graph or Inverse of the node's average geodesic distance to others in the network was found 3. Eigenvector i.e. centrality proportional to the sum of connection centralities) or Values of the first eigenvector of the graph matrix was found 4. Betweenness i.e. centrality based on a broker position connecting others or Number of geodesics that pass through the node or the edge was found

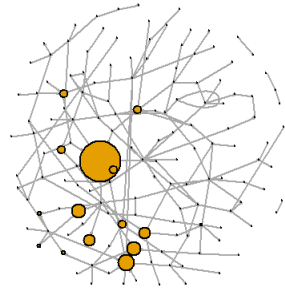
### 13.Finding Hubs and authorities

```
hs <- hub_score(g4, weights=NA)$vector
as <- authority_score(g4, weights=NA)$vector
par(mfrow=c(1,2))
plot(g4, vertex.label=NA, edge.arrow.size=.05, vertex.size=hs*50, main="Hubs")
plot(g4, vertex.label=NA, edge.arrow.size=.05, vertex.size=as*30, main="Authorities")
```

## Hubs



## Authorities



Result: Hubs and authorities were found with hubs contain catalogs with a large number of outgoing links; while authorities get many incoming links from hubs, presumably because of their high-quality relevant information.

Conclusion: Visualization of Network and it's node descriptive using Density, Recircuity, Transitivity, Diameter, Node degrees, Degree distribution, Centrality & centralization, Hubs and authorities were applied