Social Network Analysis for Project SMEs using with RStudio. Version 3 (work in progres)

Wieteska, Michal

- The of this project is an analysis of SMEs (Subject Matter Experts) invited to the project to provide specialty expertise with regards to ptoejct scope/ deliverabled. The approach take here isusing "social network analysis" concept (see wikipedia link below) with the aim to understand a community by mapping the relationships. These relationships connect them as a network, and then trying to draw out key individuals, groups within the network, associations between the individuals, outline connections intensivity etc. A network is simply a number of nodes that are connected by links. These nodes are people (here SMEs) and the links are any social connection between them; here based on interaction justified by working on the same project/ theme.
- A general concept: see wikipedia: https://en.wikipedia.org/wiki/Social_network_analysis
- for key therms explanation see wikipedia https://en.wikipedia.org/wiki/Vertex_(graph_theory)

Starting wit RStudio

Set proper pdf encoding

Remove all lists

```
ls()
```

```
## character(0)
```

```
rm(list = ls())
```

Install

install.packages("igraph")

Load needed packages

```
library(igraph)
```

```
## Warning: package 'igraph' was built under R version 3.6.3

##
## Attaching package: 'igraph'

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

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

Read data - manual file location/ selection

```
SMEnetw <- read.csv(file.choose(), header = T, sep = ";", fileEncoding="UTF-8-BOM")
SME_analysis <- data.frame(SMEnetw$SMEstart, SMEnetw$SMEend, SMEnetw$ContactFrequency)
library(igraph)
SMEnetwork <- graph.data.frame(SME_analysis, directed = TRUE)
```

Network analysis key definitions & functions (igraph package)

- Data structure: str(SMEnetw)
- Edge (link between nodes), example: edge_density(SMEnetwork, loops = T), example: ecount(SMEnetwork)
- Vertex (node apex, point of connection for links), example: vcount(SMEnetwork)
- Reciprocity, example: reciprocity(SMEnetwork)

- Closeness, example: closeness(SMEnetwork, mode='all', weights = NA)
- Betweennes - a Unique links to others in the network i.e. who gets most connections, example: betweenness(SMEnetwork, directed=TRUE, weights = NA)
- Degree - Connected to many individuals, number of connections: degree(SMEnetwork)
- Matrix - contingency table: SMEnetwork[]
- See number of
  - all connections: degree(SMEnetwork, mode='all')
  - incoming connections: degree(SMEnetwork, mode='in')
  - outcoming connections: degree(SMEnetwork, mode='out')
  - see a network diameter: diameter(SMEnetwork, directed=F, weigths=NA)

Imported data view to understand data structure

```
str(SMEnetw)
```

```
## 'data.frame':    264 obs. of  3 variables:
##  $ SMEstart        : Factor w/ 16 levels "A","B","C","D",..: 1 13 4 6 5 12 7 15 2 10 ...
##  $ SMEend          : Factor w/ 18 levels "A","B","D","E",..: 18 2 11 17 7 18 2 11 17 7 ...
##  $ ContactFrequency: int  4 2 5 7 8 5 3 5 7 8 ...
```

```r
head(SMEnetwork)
```

```
## 6 x 20 sparse Matrix of class "dgCMatrix"

##    [[ suppressing 20 column names 'A', 'S', 'D' ... ]]

##
## A . 1 2 1 2 2 3 1 1 1 . 1 . . . . . . . .
## S 1 . 1 1 2 4 3 4 1 1 1 1 1 . . . 5 . . .
## D . 2 . . 2 6 3 2 2 1 3 1 . . . . 1 . 2 .
## F 2 4 1 . . 2 3 1 1 2 3 1 . . . 1 3 . . .
## E 2 2 2 2 . 1 2 2 . 1 5 1 . . . 1 1 3 . .
## R 3 3 2 2 . . 2 3 2 . 2 2 . . . . . . 2 2
```

```r
tail(SMEnetwork)
```

```
## 6 x 20 sparse Matrix of class "dgCMatrix"

##    [[ suppressing 20 column names 'A', 'S', 'D' ... ]]

##
## E 2 2 2 2 . 1 2 2 . 1 5 1 . . . 1 1 3 . .
## R 3 3 2 2 . . 2 3 2 . 2 2 . . . . . . 2 2
## G 1 4 3 2 2 1 . 1 3 2 . 2 . . . 1 1 1 . .
## V . 1 2 3 1 1 . . 1 2 3 . 1 . . . . . . .
## B . . 2 2 1 1 1 . . 2 3 1 . . . . . . . .
## N 1 3 . 2 . 2 1 . . . 1 2 1 . . . . . . .
```

```r
degree(SMEnetwork)
```

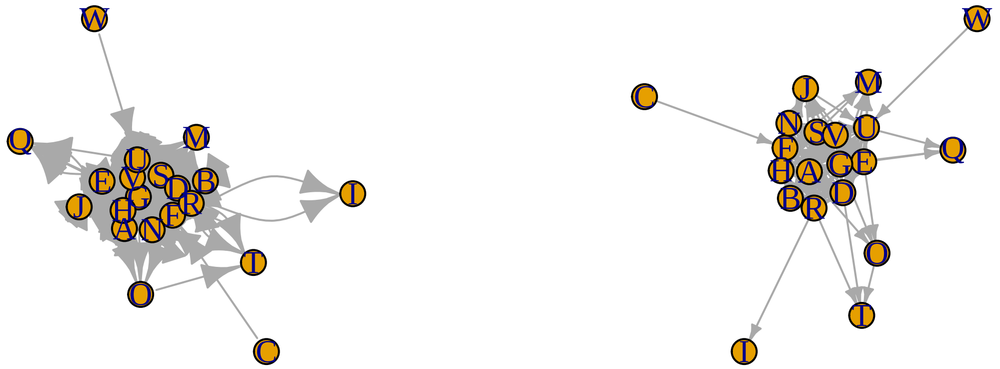
```
##  A  S  D  F  E  R  G  V  B  N  U  H  J  C  W  O  M  Q  T  I
## 27 50 46 44 42 54 49 34 25 28 52 29 18  1  1  4 12  5  5  2
```

```r
SMEnetwork[]
```

```
## 20 x 20 sparse Matrix of class "dgCMatrix"

##    [[ suppressing 20 column names 'A', 'S', 'D' ... ]]

##
## A . 1 2 1 2 2 3 1 1 1 . 1 . . . . . . . .
## S 1 . 1 1 2 4 3 4 1 1 1 1 1 . . . 5 . . .
## D . 2 . . 2 6 3 2 2 1 3 1 . . . . 1 . 2 .
## F 2 4 1 . . 2 3 1 1 2 3 1 . . . 1 3 . . .
## E 2 2 2 2 . 1 2 2 . 1 5 1 . . . 1 1 3 . .
## R 3 3 2 2 . . 2 3 2 . 2 2 . . . . . . 2 2
## G 1 4 3 2 2 1 . 1 3 2 . 2 . . . 1 1 1 . .
## V . 1 2 3 1 1 . . 1 2 3 . 1 . . . . . . .
## B . . 2 2 1 1 1 . . 2 3 1 . . . . . . . .
## N 1 3 . 2 . 2 1 . . . 1 2 1 . . . . . . .
## U 1 3 5 . 4 4 3 3 . . . 3 . . . . 1 1 . .
## H 1 . 1 3 . 3 1 2 1 1 . . 1 . . . . . . .
## J . 1 . 1 3 2 3 . . 2 2 . . . . . . . . .
## C . . . 1 . . . . . . . . . . . . . . . .
## W . . . . . . . . . . 1 . . . . . . . . .
## O . . . . . . . . . . . . . . . . . . 1 .
## M . . . . . . . . . . . . . . . . . . . .
## Q . . . . . . . . . . . . . . . . . . . .
## T . . . . . . . . . . . . . . . . . . . .
## I . . . . . . . . . . . . . . . . . . . .
```

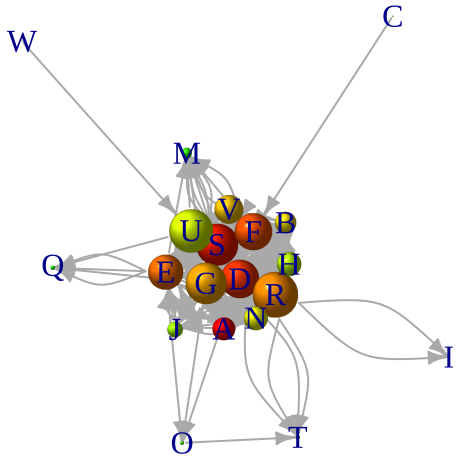
A basic vs simplified graph (removed loops in the graph, multiple edges)

```r
par(mfrow=c(1,2))
plot(SMEnetwork)

SMEnetwork_nl <- simplify(SMEnetwork, remove.multiple = T, remove.loops = T)
plot(SMEnetwork_nl, edge.arrow.size=.4) # no loops
```



Modified basic plot

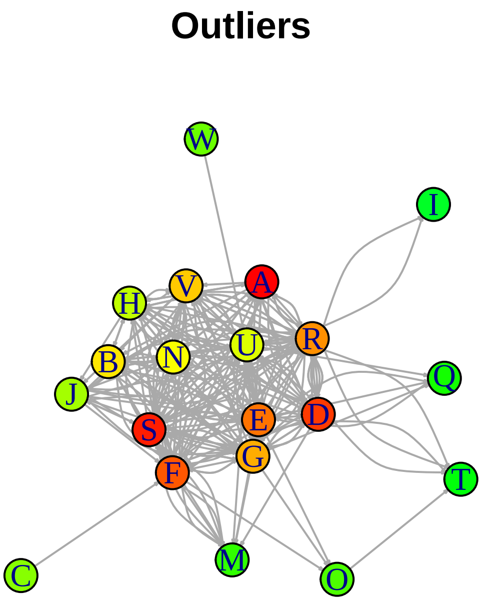
```
V(SMEnetwork)$ContactFrequency <- degree(SMEnetwork)

plot(SMEnetwork,
     vertex.color = rainbow(53),
     vertex.shape="sphere",
     vertex.size = V(SMEnetwork)$ContactFrequency*0.4,
     edge.arrow.size = 0.5,
     layout=layout.fruchterman.reingold)
```



- Network very dense with a couple of outliers, seems like a key interactions ara happening within 1 group

A view on outliers (probe)

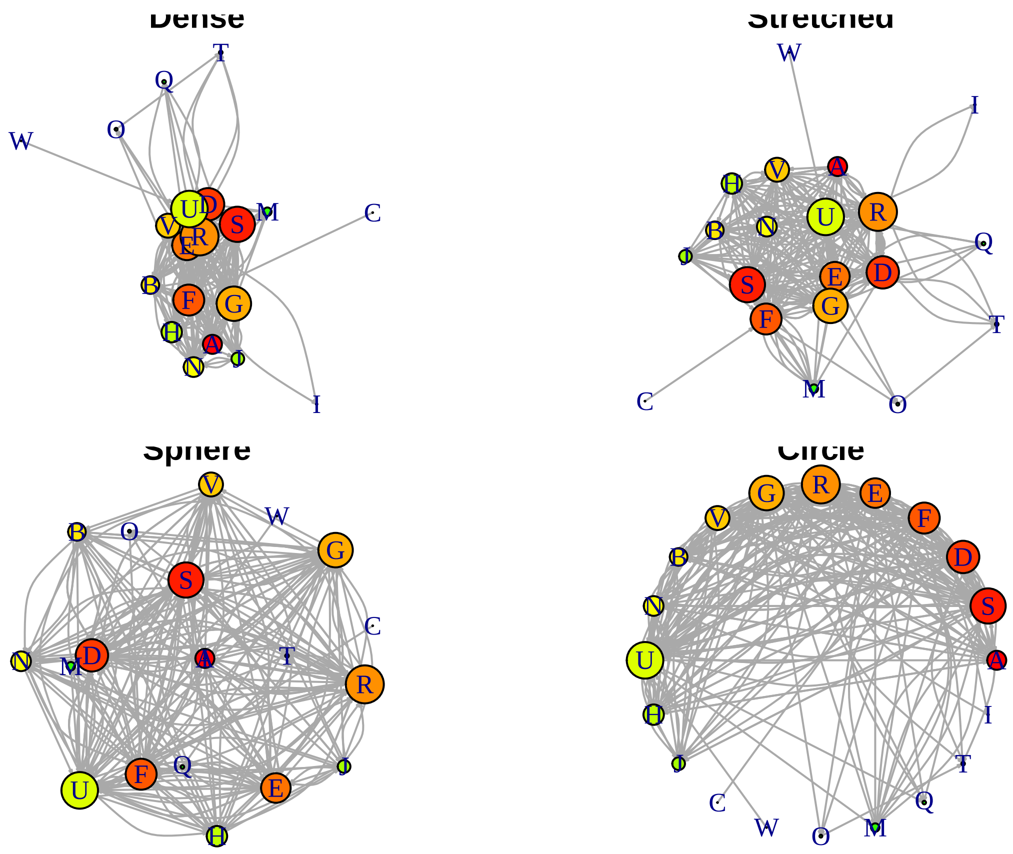
```
plot(SMEnetwork,
     vertex.color = rainbow(53),
     # vertex.size = V(SMEnetwork)$degree*0.4,
     edge.arrow.size = 0.1,
     layout=layout.kamada.kawai,
     main="Outliers",
     cex.main=0.2,
     font.main=2)
```



* Comments: 7 outlier identified with diversified number of connections startinf from 1

4 different view to get more insight

```
par(mfrow=c(2,2))
par(mar=c(0.25,0.25,0.1,0.1))
plot(SMEnetwork,
     vertex.color = rainbow(53),
     vertex.size = V(SMEnetwork)$ContactFrequency*0.4,
     edge.arrow.size = 0.1,
     main="Dense",
     cex.main=0.5,
     font.main=1,
     layout=layout.graphopt)
plot(SMEnetwork,
     vertex.color = rainbow(53),
     vertex.size = V(SMEnetwork)$ContactFrequency*0.4,
     edge.arrow.size = 0.1,
     main="Stretched",
     cex.main=0.5,
     font.main=1,
     layout=layout.kamada.kawai)
plot(SMEnetwork,
     vertex.color = rainbow(53),
     vertex.size = V(SMEnetwork)$ContactFrequency*0.4,
     edge.arrow.size = 0.1,
     main="Sphere",
     cex.main=0.5,
     font.main=1,
     layout=layout.sphere)
plot(SMEnetwork,
     vertex.color = rainbow(53),
     vertex.size = V(SMEnetwork)$ContactFrequency*0.4,
     edge.arrow.size = 0.1,
     main="Circle",
     cex.main=0.5,
     font.main=1,
     layout=layout.circle)
```

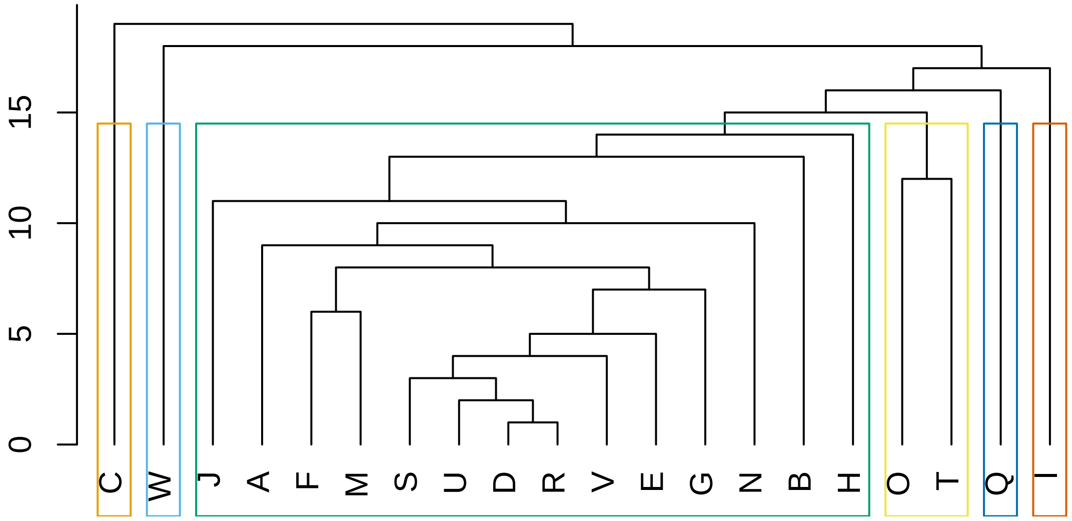


* Comments: visually it looks like R, S and U are actors with the most connections

Community detection (identify, outline grahically community areas)

by dendrogram

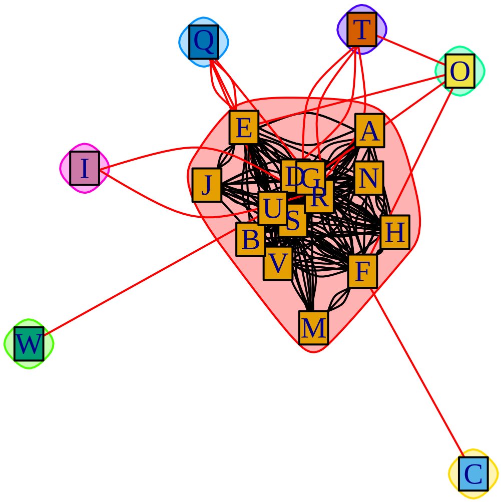
```
par(bg="white") # set background

ceb <- cluster_edge_betweenness(SMEnetwork)
dendPlot(ceb, mode="hclust")      # plot(hcd, type = "triangle", ylab = "Height")
```



* Comments: a big group of SMEs sit close interaction identified (green outline)

by network

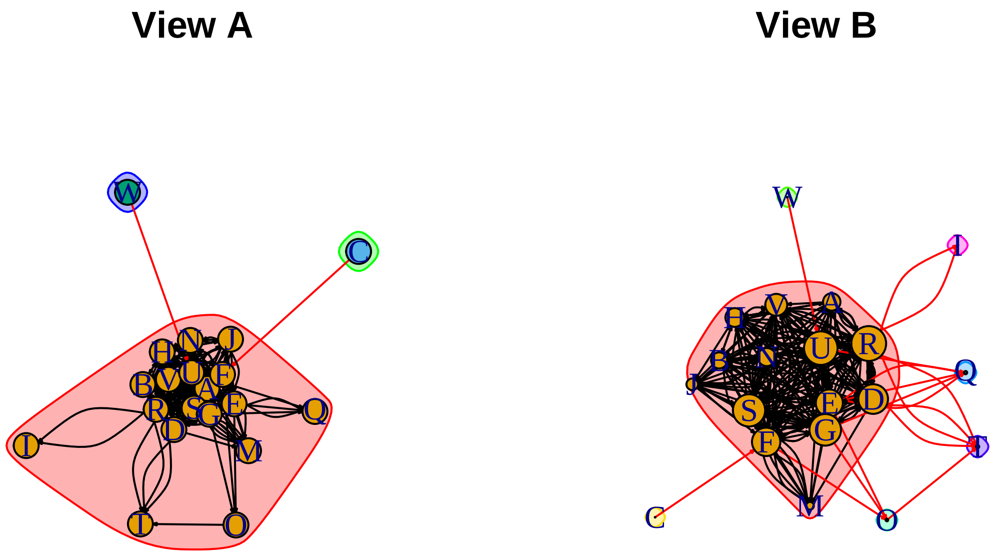
```
SMEnetwork1 <- igraph::as_data_frame(SMEnetwork)
SMEnetwork2 <- graph.data.frame(SMEnetwork1, directed = F)
cnet <- cluster_edge_betweenness(SMEnetwork2)

plot(cnet,
     SMEnetwork,
     vertex.size = 13,
     vertex.label.cex = 0.9,
     edge.arrow.size=0.1,
     vertex.shape="rectangle",
     vertex.label.dist=0.0,
     edge.arrow.mode=0,
     vertex.size = V(SMEnetwork2)$ContactFrequency*0.2,
     layout=layout.graphopt)
```



Outlining paths - 3 views

```
par(mfrow=c(1,2))

clp <- cluster_label_prop(SMEnetwork)

plot(clp, SMEnetwork,
     edge.arrow.size = 0.1,
     main="View A",
     cex.main=0.5,
     font.main=1,)



SMEnetwork1 <- igraph::as_data_frame(SMEnetwork)
```

```
SMEnetwork2 <- graph.data.frame(SMEnetwork1, directed = F)
cnet <- cluster_edge_betweenness(SMEnetwork2)



plot(cnet,
     SMEnetwork,
     vertex.color = rainbow(53),
     vertex.size = V(SMEnetwork)$ContactFrequency*0.4,
     edge.arrow.size = 0.1,
     main="View B",
     cex.main=0.1,
     font.main=1,
     layout=layout.kamada.kawai)
```



View A

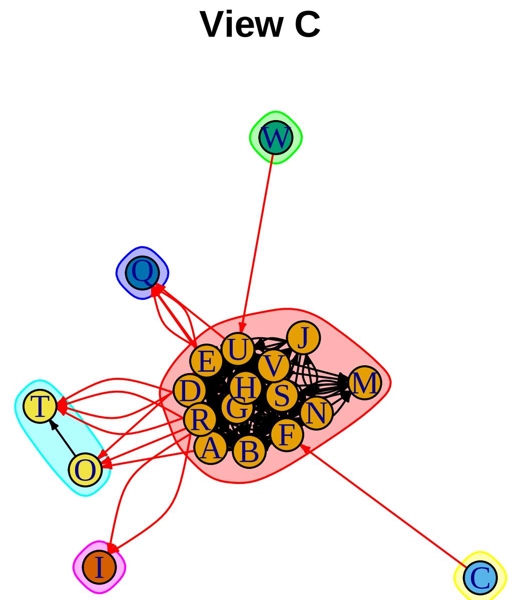
View B

. . . cont.

```
# greedy method
coords = layout_with_fr(SMEnetwork)

c3 = cluster_edge_betweenness(SMEnetwork  * 1.5)

# modularity measure
modularity(c3)
```

```
## [1] 0.006011823
```

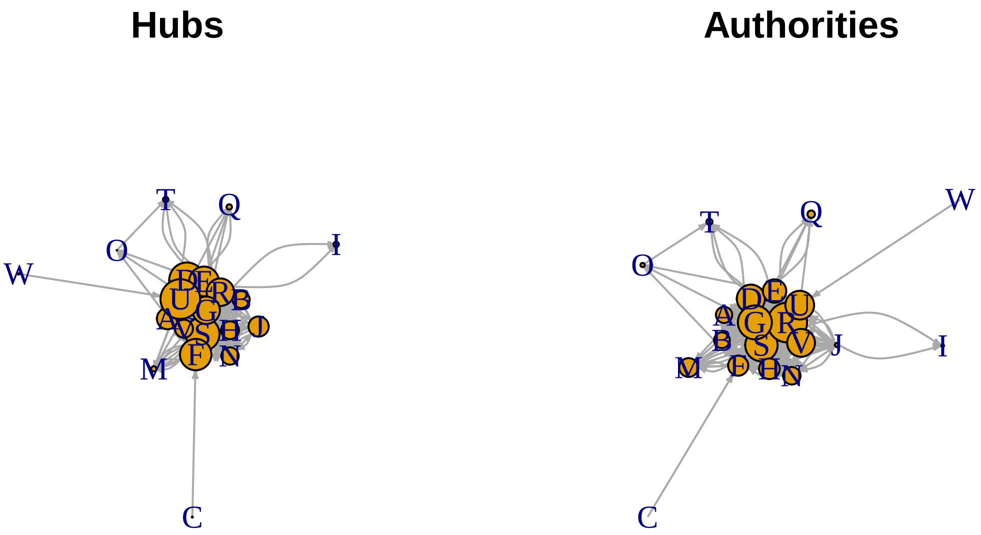
```
# plot communities with shaded regions
plot_shaded_view <- plot(c3, SMEnetwork, edge.arrow.size = 0.25, layout=coords, main="View C"); plot_sha
```



```
## NULL
```

Identification of Hubs and Authorities

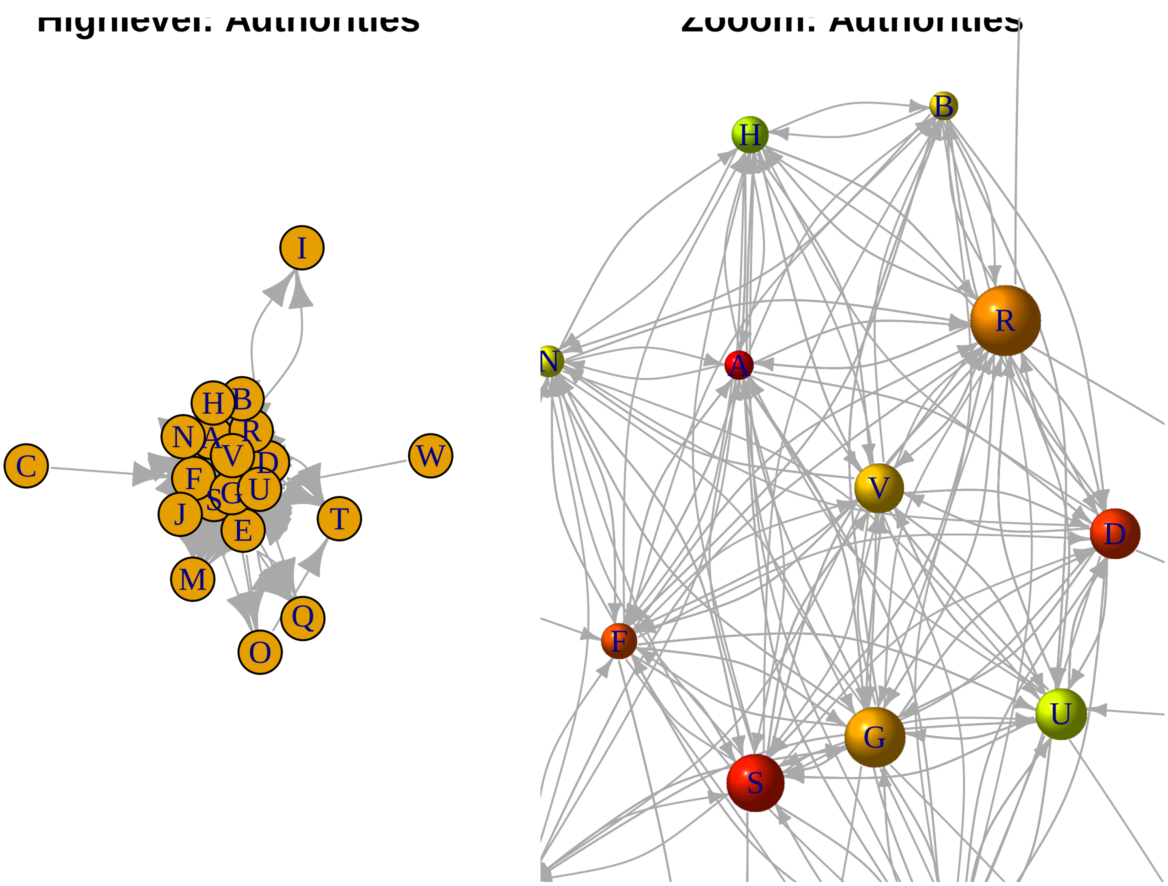
```
hs <- hub_score(SMEnetwork, weights=NA)$vector

as <- authority_score(SMEnetwork, weights=NA)$vector



par(mfrow=c(1,2))

 plot(SMEnetwork, vertex.size=hs*25, main="Hubs", edge.arrow.size = 0.2)

 plot(SMEnetwork, vertex.size=as*25, main="Authorities", edge.arrow.size = 0.2)
```



```
#distances(SMEnetwork)
```

Zoom

```
par(mfrow=c(1,2), mar=c(0,0,0,0))

l <- layout_with_fr(SMEnetwork)
l <- norm_coords(l, ymin=-1, ymax=1, xmin=-1, xmax=1)


plot(SMEnetwork, main="Highlevel: Authorities", rescale=F, layout=l*0.7, cex.main=0.1)
plot(SMEnetwork, vertex.shape="sphere", vertex.color = rainbow(53), vertex.size=as*25, main="Zooom: Aut
```



```
# edge.color=c("gold", "blue",  "tomato", "grey", "red", "yellowgreen", "black"), rescale=F, layout=l*
```

Additional analysis (degree etc.)

```
degree(SMEnetwork)
```

```
##  A  S  D  F  E  R  G  V  B  N  U  H  J  C  W  O  M  Q  T  I
## 27 50 46 44 42 54 49 34 25 28 52 29 18  1  1  4 12  5  5  2
```

```
reciprocity(SMEnetwork)
```

```
## [1] 0.530303
```

```
closeness(SMEnetwork, mode='all', weights = NA)
```

```
##          A          S          D          F          E          R          G
## 0.03703704 0.04000000 0.04000000 0.04347826 0.04347826 0.04166667 0.04347826
##          V          B          N          U          H          J          C
## 0.03846154 0.03703704 0.03846154 0.04347826 0.03846154 0.03448276 0.02439024
##          W          O          M          Q          T          I
## 0.02439024 0.02777778 0.03030303 0.02631579 0.02631579 0.02380952
```

```
betweenness(SMEnetwork, directed=TRUE, weights = NA)
```

```
##          A          S          D          F          E          R          G
##  1.3005434  8.7400682  8.4077597 26.2159434  9.6454008 26.0980151 13.8489753
##          V          B          N          U          H          J          C
##  4.5213026  0.9154637  3.1412153 25.1877259  3.8342740  0.6036301  0.0000000
##          W          O          M          Q          T          I
##  0.0000000  0.5396825  0.0000000  0.0000000  0.0000000  0.0000000
```

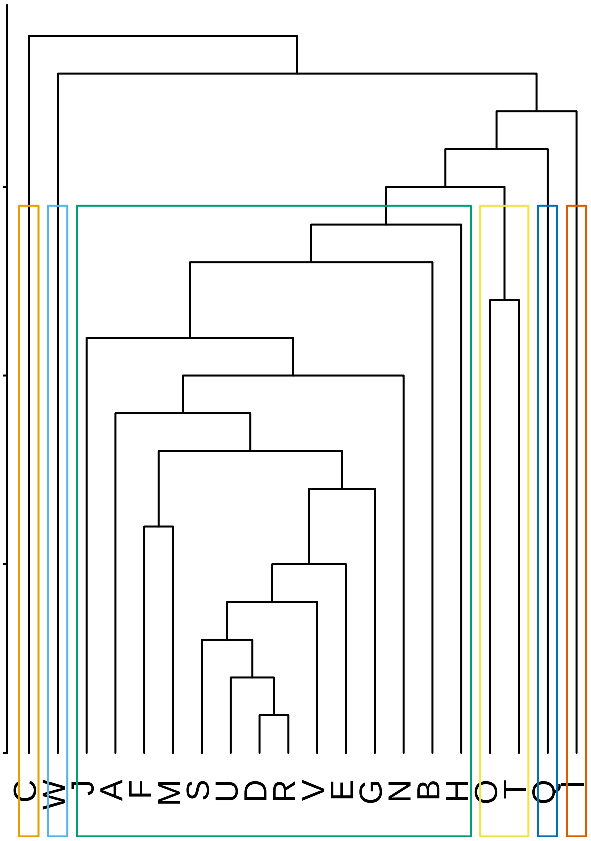
- Appendix - Additional view

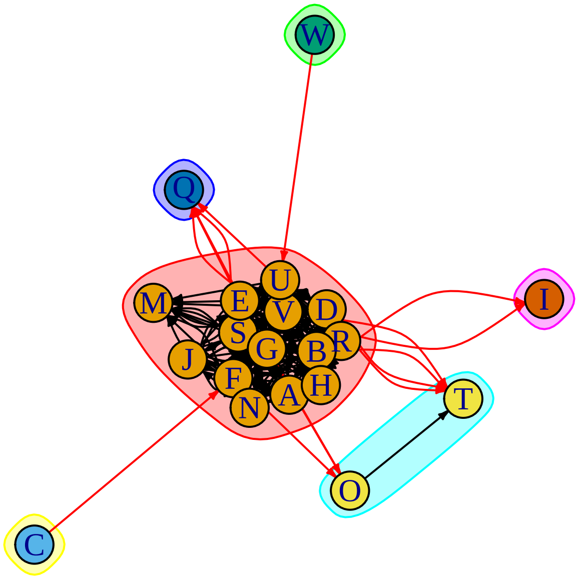
clustering

```
par(mfrow=c(1,2))
par(mar=c(0.1,0.1,0.75,0.75))

par(bg="white") # set background

ceb <- cluster_edge_betweenness(SMEnetwork)
dendPlot(ceb, mode="hclust")     # plot(hcd, type = "triangle", ylab = "Height")


# greedy method (hiearchical, fast method)
coords = layout_with_fr(SMEnetwork)

c3 = cluster_edge_betweenness(SMEnetwork  * 1.5)

# modularity measure
modularity(c3)
```

```
## [1] 0.006011823
```

```
# plot communities with shaded regions
plot_shaded_view <- plot(c3, SMEnetwork, edge.arrow.size = 0.25, layout=coords); plot_shaded_view
```





```
## NULL
```

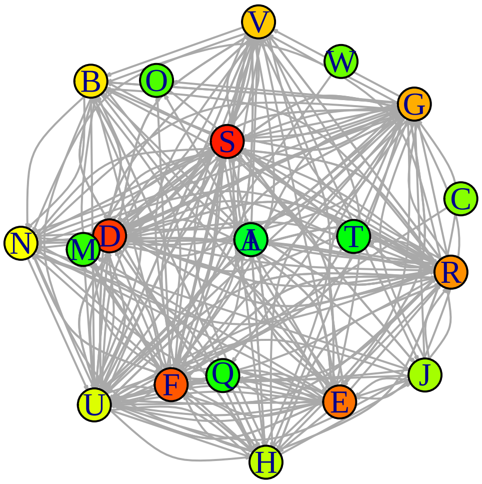
comments: 6 outliers identified for dendrogram (outside green box) and network diagram (outside red area)

additional analysis - do some some zoom for details

- Other views

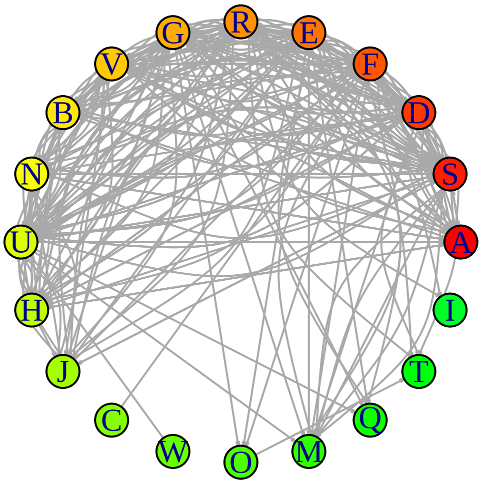
spherical view

```
plot(SMEnetwork,
     vertex.color = rainbow(53),
     # vertex.size = V(SMEnetwork)$degree*0.4,
     edge.arrow.size = 0.1,
     layout=layout.sphere)
```



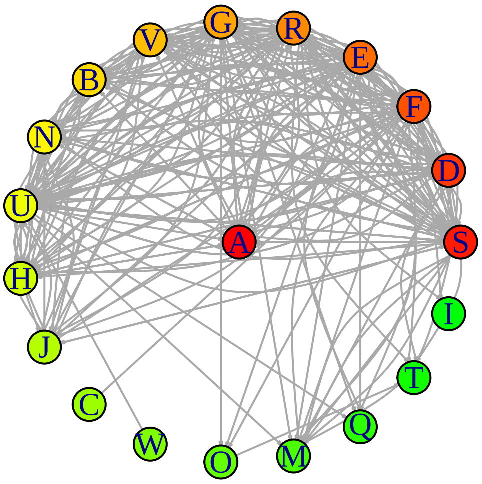
circle

```
plot(SMEnetwork,
     vertex.color = rainbow(53),
     # vertex.size = V(SMEnetwork)$degree*0.4,
     edge.arrow.size = 0.1,
     layout=layout.circle)
```



#star

```r
plot(SMEnetwork,
     vertex.color = rainbow(56),
     # vertex.size = V(SMEnetwork)$degree*0.4,
     edge.arrow.size = 0.1,
     layout=layout.star)
```


G
R
V
E
B
F
N
D
U
A
S
H
I
J
T
C
Q
W
M
O