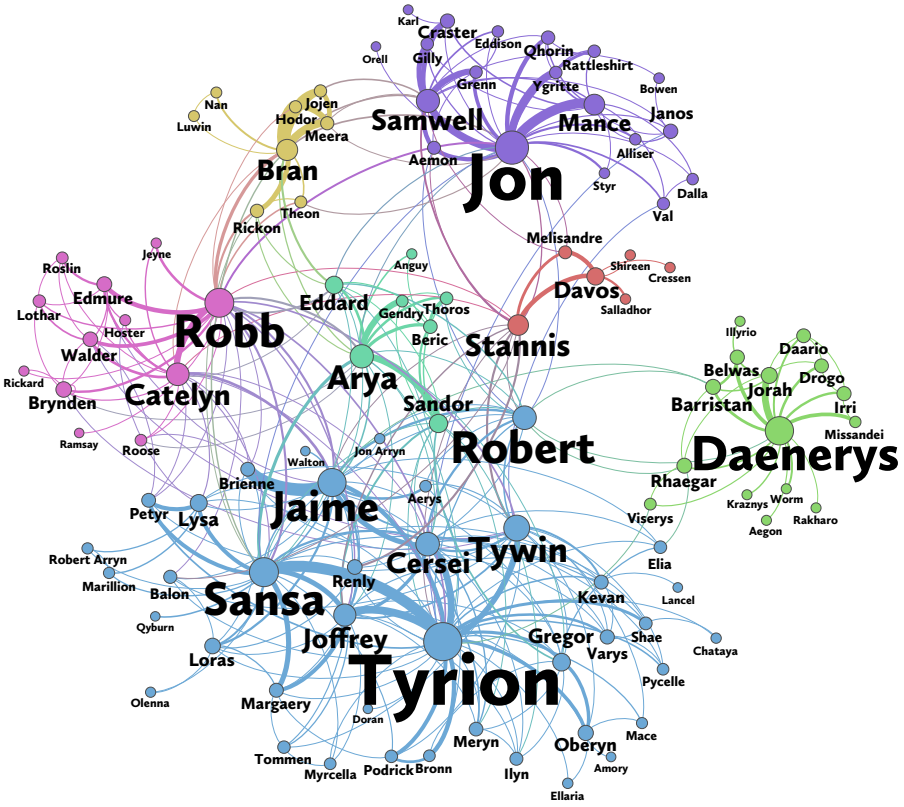
Exercises Day 1-1: Drawing Networks in R

Oldenburg, 11/01/2018

Part 1: Visualizing the network

In these exercises, we will analyse a social network of book series *A Song of Ice and Fire*, on which the popular TV show *Game of Thrones* is based. This network was recently published in Math Horizons Magazine (Beveridge & Shan, 2016), and is based on the third book, A Storm of Swords, on which the third and fourth season of the TV series are based (so no spoilers on the current season ;)). More information, including the data, is available online. The network published is the following:



For these exercises, please refer to the Network analysis cookbook, the course materials, and the qgraph manual.

Exercise 1 Look through the paper to get an idea of what this network represents. What do the nodes and edges represent?
Solution: Nodes represent characters and edges the number of times they are mentioned together. ■

The data as published online can be loaded in R as follows:

```
Data <- read.csv("stormofswords.csv")
```

Exercise 1 Look at the data in RStudio using the 'View' function. This matrix encodes a network. Can you figure out how? What do the rows stand for and what do the columns stand for?
Solution: Each row indicates an edge. The first and second columns indicate the nodes an edge is connected to and the third column indicates the strength of connection. ■

This structure is known as an *edgelist* encoding a network, which can also be used as input for qgraph:

```
library("qgraph")
qgraph(Data, directed = FALSE)
```

Exercise 2 Why did I had to use the `directed` argument? What does it do?

Solution: An edgelist does not know if edges are directed (one-way) or undirected, so we needed to spefify that. ■

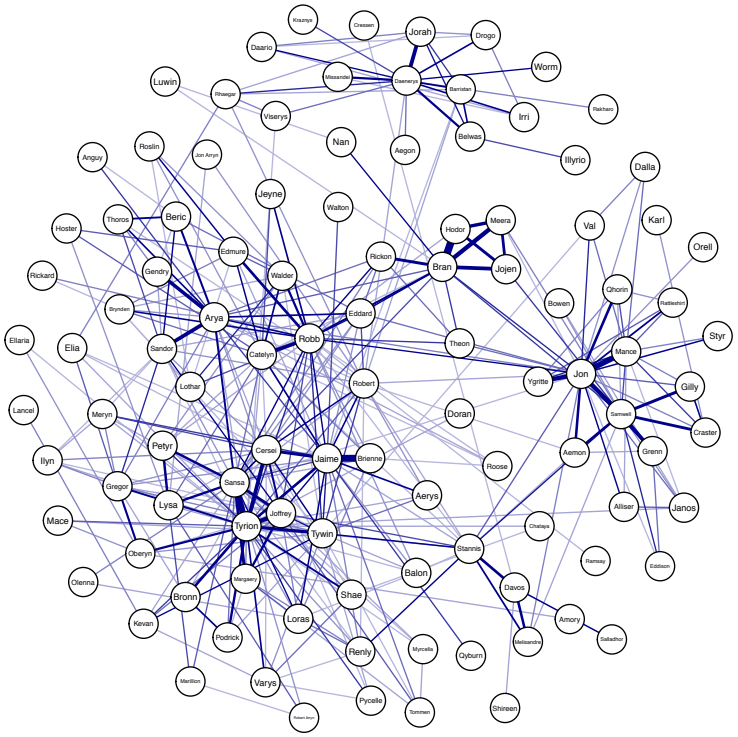
Now load the following dataset:

```
Data2 <- read.csv("stormofswords_wmat.csv")
```

This dataset represents the same network, but in a different way. This representation is called a *weights matrix*.

Exercise 3 Investigate the new data using `View(Data2)`. Can you figure out how this weights matrix encodes a network. Use `Data2` as input to `qgraph()`. Do you obtain the same network? Do you still need to use the `directed` argument?
Solution: When the weights matrix is symmetrical, it is automatically treated as undirected. Hence, we no longer needed the `directed` argument. ■

The plotted network is plotted using a circular layout. This circular layout, however, is hard to interpret and read in such networks with many nodes. In addition, I like to plot edges with a different color than green when they represent values that can only be positive. Finally, the nodes are very large and we might want to make them smaller:



Exercise 4 Recreate the plot above, changing the layout to a spring layout, the edge color to ‘"darkblue"‘ and the node size to 3. Look at the qgraph help page to figure out the commands needed (`?qgraph`). Note: your computer might generate a different spring layout (nodes placed on different locations).
Solution: `qgraph(Data, directed = FALSE, layout = "spring",posCol = "darkblue", vsize = 3).` ■

qgraph uses three arguments that need to be known to interpret a network: `minimum`, `cut`, and `maximum`. These are set automatically, and can be shown using the argument `details = TRUE`.

Exercise 5 What values did qgraph set to `cut` and `maximum`? Note: `minimum` is always set to 0 by default and not shown with `details = TRUE` unless it differs from 0.
Solution: qgraph set cut to 14 and maximum to 96. ■

The `minimum` argument can be used to *hide* edges with an absolute (negative edges are treated as positive) weight under some value. Note that these edges are only visually hidden, not removed in further analyses (which can be done using the `threshold` argument). This argument is useful when plotting dense graphs (e.g., correlation networks) but *not* recommended in the networks estimated in this summer school.

Exercise 6 Set the `minimum` argument to 1, 5 and 10 while using a spring layout. How does the network change? Do the same using the `threshold` argument. Can you explain why the layout remains the same using `minimum` but changes using `threshold`?
Solution: Minimum does not remove edges, hence the layout is the same. The networks only visually differ. ■

Edges drawn in qgraph are drawn more wider and more saturated the stronger the absolute edge weight is. In large networks, it might be useful to split the scaling of width and color. This is what the `cut` argument does: edges with an absolute edge weight under the cutoff will be drawn of the smallest width and vary only in color. Edges with an absolute edge weight over the cutoff value will always be drawn fully saturated (green or red by default), and will be drawn thicker the stronger they are. You can disable this behavior by setting `cut = 0`, which will ensure that edges all scale in color and width. qgraph automatically sets a cutoff value when there are 20 or more nodes in the network. We recommend setting `cut = 0` unless you specifically want this behavior.

Exercise 7 Set the `cut` argument to 50, 10 and 1 while using a spring layout. How does the network change? Now set the `cut` argument to 0. What happened?
Solution: The higher cut is set, the less edges are highlighted. Setting cut to 0 disabled the cutoff. ■

The scaling of edges is chosen based on the strongest absolute edge in the network. This is because networks highly differ in their weights. This social network is based on the number of interactions. The characters "Bran" and "Hodor" interacted the most (96 times), leading to a strongest edge weight of 96. A network based on (partial) correlations, however, can never have a stronger edge weight than 1 (and usually features weaker edges). The `maximum` argument can be used to overwrite the "largest edge" to which the color and width of edges scale to. Its value is treated as the weight of an invisible edge, and is automatically set to the largest edge weight in the network. Setting `maximum` higher will make edges scale to that value instead of the strongest edge.

Exercise 8 Set the `maximum` argument to 200. What happened? Now set `maximum` back to its default and subsequently to 10. Why doesn't `maximum = 10` change the network from its default value, but `maximum = 200` does?
Solution: Setting maximum below the strongest edge in the network does nothing: the edg weight width and saturation scale to is still the strongest edge weight and not the maximum score then. ■

Exercise 9 What would be a good setting for `maximum` when drawing networks based on (partial) correlations?
Solution: 1 ■

Part 2: Analyzing the network

Now that we can visualize the network, we might wish to analyze it further. To do this, we first need to store the network:

```
Graph <- qgraph(Data, directed = FALSE, layout = "spring")
```

Now we can obtain the weights matrix for further analysis (this is how I obtained `Data2`):

```
WeightMat <- getWmat(Graph)
```

It's column names tells us the labels of each node:

```
Labels <- colnames(WeightMat)
```

Now we can see that Jon Snow is node 32:

```
which(Labels == "Jon")

## [1] 32
```

and Daenerys is node 17:

```
which(Labels == "Daenerys")

## [1] 17
```

One option is to analyze how important or *central* nodes are in the network. We will discuss these in more detail on Wednesday, and a description of how these measures can be computed can be found in Opsahl, Agneessens, and Skvoretz (2010). These can be analyzed using the `centrality` function:

```
Centrality <- centrality(Graph, all.shortest.paths = TRUE)
```

Node strength (also called degree) sums the connected edge weights to a node. The node strength of Jon and Deanerys are:

```
Centrality$OutDegree[c(17, 32)]

## Daenerys      Jon
##      232      442
```

Closeness computes how "close" two nodes are together in the network:

```
Centrality$Closeness[c(17, 32)]

##   Daenerys        Jon
## 0.02612782 0.04305410
```

Finally, *Betweenness* computes how often one node is featured in the most efficient (shortest) paths between other node:

```
Centrality$Betweenness[c(17, 32)]

## Daenerys      Jon
##     2200     2838
```

Based on these results, Jon seems more important in this book.

Exercise 10 Compare the centrality of the character named "Tyrion" to those of Jon and Daenerys.
Solution:

```
# Tyrion is node:
which(Labels == "Tyrion")
[1] 64

# Centrality:
Centrality$OutDegree[64]
Tyrion
   551
Centrality$Closeness[64]
    Tyrion
0.05291881
Centrality$Betweenness[64]
Tyrion
  3938
# Tyrion is more central!
```

■

We can also look at how "close" Jon and Daenerys are:

```
Centrality$ShortestPathLengths[17,32]

## [1] 0.3969188
```

The following characters connect Jon and Daenerys:

```
Labels[Centrality$ShortestPaths[[17,32]][[1]]]

## [1] "Daenerys" "Robert"   "Jaime"    "Robb"     "Jon"
```

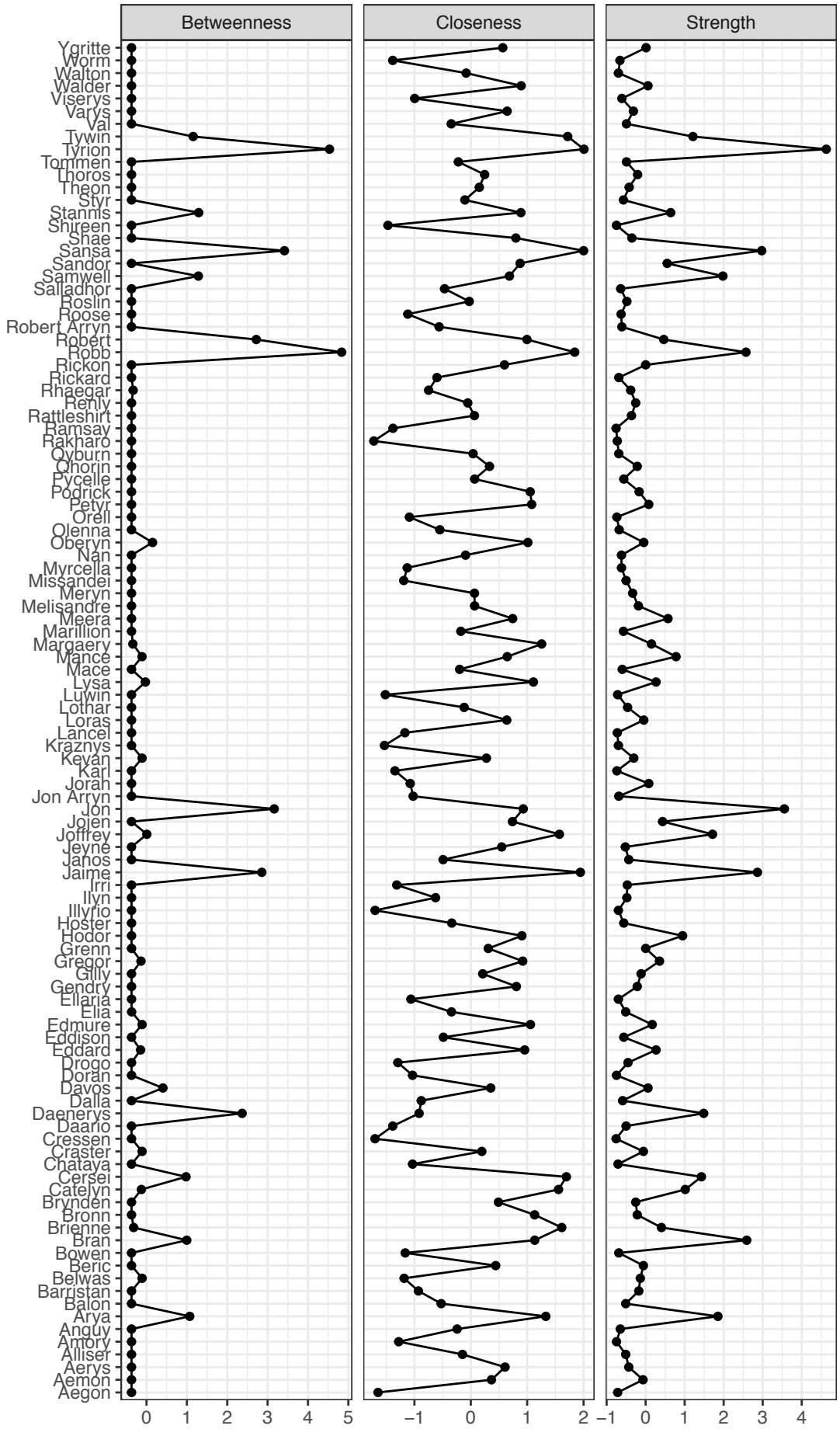
Exercise 11 Via which characters is Tyrion connected to Jon and Daenerys?
Solution:

```
# Tyrion to Jon:
> Labels[Centrality$ShortestPaths[[64,32]][[1]]]
[1] "Tyrion" "Sansa"  "Robb"   "Jon"

# Tyrion to Daenerys:
> Labels[Centrality$ShortestPaths[[64,17]][[1]]]
[1] "Tyrion"   "Cersei"   "Robert"   "Daenerys"
```

■

We can plot the centrality indices using the `centralityPlot` function:

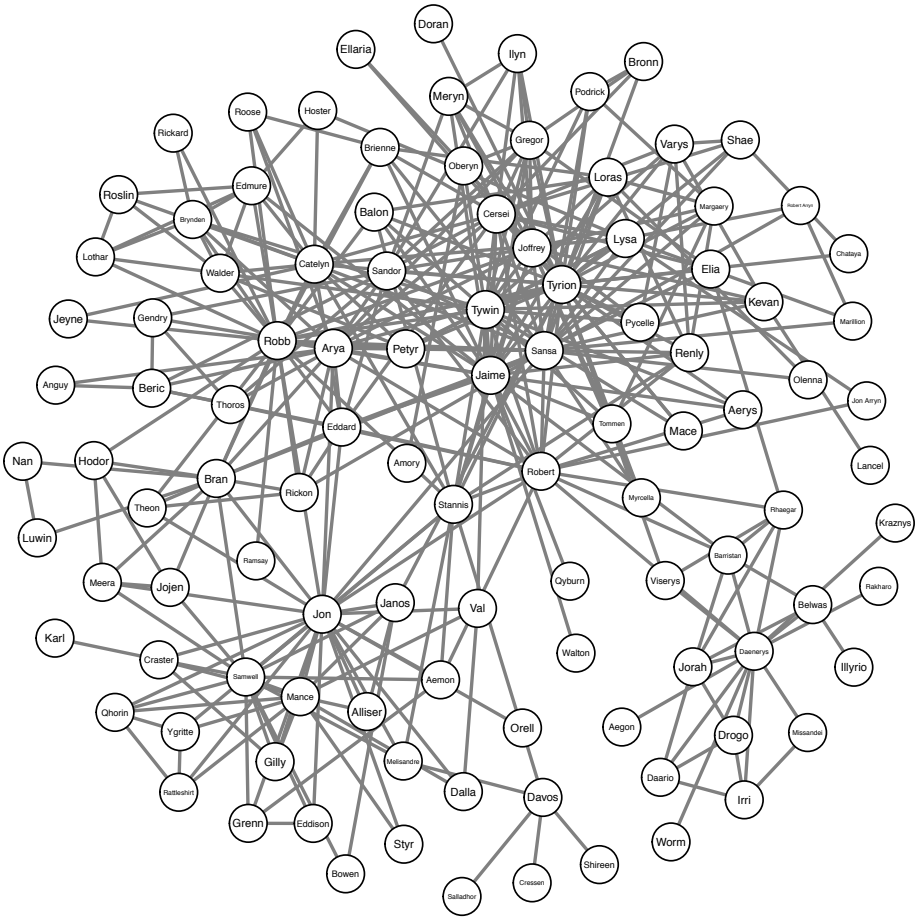
```
centralityPlot(Graph)

## Note:  z-scores are shown on x-axis rather than raw centrality indices.
```


Betweenness
Closeness
Strength
Ygritte
Worm
Walton
Walder
Viserys
Varys
Val
Tywin
Tyrion
Tommen
Thoros
Theon
Styr
Stannis
Shireen
Shae
Sansa
Sandor
Samwell
Salladhor
Roslin
Roose
Robert Arryn
Robert
Robb
Rickon
Rickard
Rhaegar
Renly
Rattleshirt
Ramsay
Rakharo
Qyburn
Qhorin
Pycelle
Podrick
Petyr
Orell
Olenna
Oberyn
Nan
Myrcella
Missandei
Meryn
Melisandre
Meera
Marillion
Margaery
Mance
Mace
Lysa
Luwin
Lothar
Loras
Lancel
Kraznys
Kevan
Karl
Jorah
Jon Arryn
Jon
Jojen
Joffrey
Jeyne
Janos
Jaime
Irri
Ilyn
Illyrio
Hoster
Hodor
Grenn
Gregor
Gilly
Gendry
Ellaria
Elia
Edmure
Eddison
Eddard
Drogo
Doran
Davos
Dalla
Daenerys
Daario
Cressen
Craster
Chataya
Cersei
Catelyn
Brynden
Bronn
Brienne
Bran
Bowen
Beric
Belwas
Barristan
Balon
Arya
Anguy
Amory
Alliser
Aerys
Aemon
Aegon
0
1
2
3
4
5
−1
0
1
2
−1
0
1
2
3
4

Exercise 12 What character would you conclude is the most central?
Solution: Tyrion. Also central are Sansa and Robb. ■

Many network analysts prefer to analyze an unweighted network rather than a weighted network. We can strip the weights by setting all edge weights to 1 or by not using the weights in the edgelist:

```
Graph_unweighted <- qgraph(Data[,1:2], directed=FALSE, repulsion = 0.7)
```



Exercise 13 What happened when I set the `repulsion` argument lower than its default of 1?
Solution: Nodes are drawn further away from each-other. ■

Exercise 14 Recreate the centrality plot using the unweighted network. Does your conclusion on the most central character change?
Solution: Tyrion is now more clearly the most central character. ■

One common analysis of such network structures is to investigate if the network exhibits a "small-world" structure. A network has a small-world structure if it is (a) structured such that it forms clusters: my friends also talk to each-other, and (b) most nodes can reach each other with only a few steps (related to the idea of "six degrees of separation"). A small-world arises due to networks being structured in clusters (my friends

talk to each other) but also featuring some random connections (due to this summer school, you now also talk to people from all over the world). For more details, see the classical paper by Watts and Strogatz (1998). We can use the `smallworldIndex` to obtain a "small-world index". This can only be computed from unweighted networks. If the index is above 3, we can conclude the network features a small world.

Exercise 15 Does the unweighted network feature a small world?
Solution: Yes:

```
smallworldIndex(Graph_unweighted)$index
[1] 4.921709
```

■

References

Beveridge, A., & Shan, J. (2016). Network of thrones. *Math Horizons*, *23*(4), 18–22.

Opsahl, T., Agneessens, F., & Skvoretz, J. (2010). Node centrality in weighted networks: Generalizing degree and shortest paths. *Social networks*, *32*(3), 245–251.

Watts, D., & Strogatz, S. (1998). Collective dynamics of'small-world'networks. *Nature*, *393*(6684), 440–442.