Introduction to social network analysis with R

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Importing network data into R

In this training session we will be using a small network that indicates interactions in the movie Star Wars Episode IV (http://evelinag.com/blog/2015/12-15-star-wars-social-network/). Here, each node is a character and each edge indicates whether they appeared together in a scene of the movie. Edges here are thus *undirected* and they also have weights attached, since they can appear in multiple scenes together.

The first step is to read the list of edges and nodes in this network:

```
edges <- read.csv("data/star-wars-network-edges.csv")
head(edges)
```

```
##      source target weight
## 1     C-3PO  R2-D2     17
## 2      LUKE  R2-D2     13
## 3   OBI-WAN  R2-D2      6
## 4      LEIA  R2-D2      5
## 5       HAN  R2-D2      5
## 6 CHEWBACCA  R2-D2      3
```

```
nodes <- read.csv("data/star-wars-network-nodes.csv")
head(nodes)
```

```
##          name id
## 1       R2-D2  0
## 2   CHEWBACCA  1
## 3       C-3PO  2
## 4        LUKE  3
## 5 DARTH VADER  4
## 6       CAMIE  5
```

For example, we learn that C-3PO and R2-D2 appeared in 17 scenes together.

How do we convert these two datasets into a network object in R? There are multiple packages to work with networks, but the most popular is `igraph` because it's very flexible and easy to do, and in my experience it's much faster and scales well to very large networks. Other packages that you may want to explore are `sna` and `networks`.

Now, how do we create the igraph object? We can use the `graph_from_data_frame` function, which takes two arguments: `d`, the data frame with the edge list in the first two columns; and `vertices`, a data frame with node data with the node label in the first column. (Note that igraph calls the nodes `vertices`, but it's exactly the same thing.)

```
library(igraph)
g <- graph_from_data_frame(d=edges, vertices=nodes, directed=FALSE)
g
```

```
## IGRAPH UNW- 22 60 --
## + attr: name (v/c), id (v/n), weight (e/n)
## + edges (vertex names):
##  [1] R2-D2      --C-3PO       R2-D2      --LUKE
##  [3] R2-D2      --OBI-WAN     R2-D2      --LEIA
##  [5] R2-D2      --HAN         R2-D2      --CHEWBACCA
##  [7] R2-D2      --DODONNA     CHEWBACCA  --OBI-WAN
##  [9] CHEWBACCA  --C-3PO       CHEWBACCA  --LUKE
## [11] CHEWBACCA  --HAN         CHEWBACCA  --LEIA
## [13] CHEWBACCA  --DARTH VADER CHEWBACCA  --DODONNA
## [15] LUKE       --CAMIE       CAMIE      --BIGGS
## + ... omitted several edges
```

What does it mean? - `U` means undirected
- `N` means named graph
- `W` means weighted graph
- `22` is the number of nodes
- `60` is the number of edges
- `name (v/c)` means *name* is a node attribute and it's a character
- `weight (e/n)` means *weight* is an edge attribute and it's numeric

This is how you access specific elements within the igraph object:

```
V(g) # nodes
```

```
## + 22/22 vertices, named:
##  [1] R2-D2       CHEWBACCA   C-3PO       LUKE        DARTH VADER
##  [6] CAMIE       BIGGS       LEIA        BERU        OWEN
## [11] OBI-WAN     MOTTI       TARKIN      HAN         GREEDO
## [16] JABBA       DODONNA     GOLD LEADER WEDGE       RED LEADER
## [21] RED TEN     GOLD FIVE
```

```
V(g)$name # names of each node
```

```
##  [1] "R2-D2"       "CHEWBACCA"   "C-3PO"       "LUKE"        "DARTH VADER"
##  [6] "CAMIE"       "BIGGS"       "LEIA"        "BERU"        "OWEN"
## [11] "OBI-WAN"     "MOTTI"       "TARKIN"      "HAN"         "GREEDO"
## [16] "JABBA"       "DODONNA"     "GOLD LEADER" "WEDGE"       "RED LEADER"
## [21] "RED TEN"     "GOLD FIVE"
```

```
vertex_attr(g) # all attributes of the nodes
```

```
## $name
##  [1] "R2-D2"       "CHEWBACCA"   "C-3PO"       "LUKE"        "DARTH VADER"
##  [6] "CAMIE"       "BIGGS"       "LEIA"        "BERU"        "OWEN"
## [11] "OBI-WAN"     "MOTTI"       "TARKIN"      "HAN"         "GREEDO"
## [16] "JABBA"       "DODONNA"     "GOLD LEADER" "WEDGE"       "RED LEADER"
## [21] "RED TEN"     "GOLD FIVE"
##
## $id
##  [1]  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21
```

```
E(g) # edges
```

```
## + 60/60 edges (vertex names):
##  [1] R2-D2      --C-3PO       R2-D2      --LUKE
##  [3] R2-D2      --OBI-WAN     R2-D2      --LEIA
##  [5] R2-D2      --HAN         R2-D2      --CHEWBACCA
##  [7] R2-D2      --DODONNA     CHEWBACCA  --OBI-WAN
##  [9] CHEWBACCA  --C-3PO       CHEWBACCA  --LUKE
## [11] CHEWBACCA  --HAN         CHEWBACCA  --LEIA
## [13] CHEWBACCA  --DARTH VADER CHEWBACCA  --DODONNA
## [15] LUKE       --CAMIE       CAMIE      --BIGGS
## [17] LUKE       --BIGGS       DARTH VADER--LEIA
## [19] LUKE       --BERU        BERU       --OWEN
## + ... omitted several edges
```

```
E(g)$weight # weights for each edge
```

```
##  [1] 17 13  6  5  5  3  1  7  5 16 19 11  1  1  2  2  4  1  3  3  2  3 18
## [24]  2  6 17  1 19  6  1  2  1  7  9 26  1  1  6  1  1 13  1  1  1  1  1
## [47]  1  2  1  1  3  3  1  1  3  1  2  1  1  1
```

```
edge_attr(g) # all attributes of the edges
```

```
## $weight
##  [1] 17 13  6  5  5  3  1  7  5 16 19 11  1  1  2  2  4  1  3  3  2  3 18
## [24]  2  6 17  1 19  6  1  2  1  7  9 26  1  1  6  1  1 13  1  1  1  1  1
## [47]  1  2  1  1  3  3  1  1  3  1  2  1  1  1
```

```
g[] # adjacency matrix
```

```
## 22 x 22 sparse Matrix of class "dgCMatrix"
```

```
##    [[ suppressing 22 column names 'R2-D2', 'CHEWBACCA', 'C-3PO' ... ]]
```

```
##
## R2-D2        .  3 17 13 . . .  5 . .  6 . .  5 . . 1 . . . . .
## CHEWBACCA    3  .  5 16 1 . . 11 . .  7 . . 19 . . 1 . . . . .
## C-3PO       17  5  . 18 . . 1  6 2 2  6 . .  6 . . . . . 1 . .
## LUKE        13 16 18  . . 2 4 17 3 3 19 . . 26 . . 1 1 2 3 1 .
## DARTH VADER  .  1  .  . . . .  1 . .  1 1 7  . . . . . . . .
## CAMIE        .  .  .  2 . . 2  . . .  . . .  . . . . . . . .
## BIGGS        .  .  1  4 . 2 .  1 . .  . . .  . . . . 1 2 3 . .

## LEIA         5 11  6 17 1 . 1  . 1 .  1 1 1 13 . . . . . 1 . .
## BERU         .  .  2  3 . . .  1 . 3  . . .  . . . . . . . .
## OWEN         .  .  2  3 . . .  . 3 .  . . .  . . . . . . . .
## OBI-WAN      6  7  6 19 1 . .  1 . .  . . .  9 . . . . . . . .
## MOTTI        .  .  .  . 1 . .  1 . .  . . 2  . . . . . . . .
## TARKIN       .  .  .  . 7 . .  1 . .  . 2 .  . . . . . . . .
## HAN          5 19  6 26 . . . 13 . .  9 . .  . 1 1 . . . . . .
## GREEDO       .  .  .  . . . .  . . .  . . .  1 . . . . . . . .
## JABBA        .  .  .  . . . .  . . .  . . .  1 . . . . . . . .
## DODONNA      1  1  .  1 . . .  . . .  . . .  . . . . 1 1 . . .
## GOLD LEADER  .  .  .  1 . . 1  . . .  . . .  . . . 1 . 1 1 . .
## WEDGE        .  .  .  2 . . 2  . . .  . . .  . . . 1 1 . 3 . .
## RED LEADER   .  .  1  3 . . 3  1 . .  . . .  . . . . 1 3 . 1 .
## RED TEN      .  .  .  1 . . .  . . .  . . .  . . . . . . 1 . .
## GOLD FIVE    .  .  .  . . . .  . . .  . . .  . . . . . . . .
```

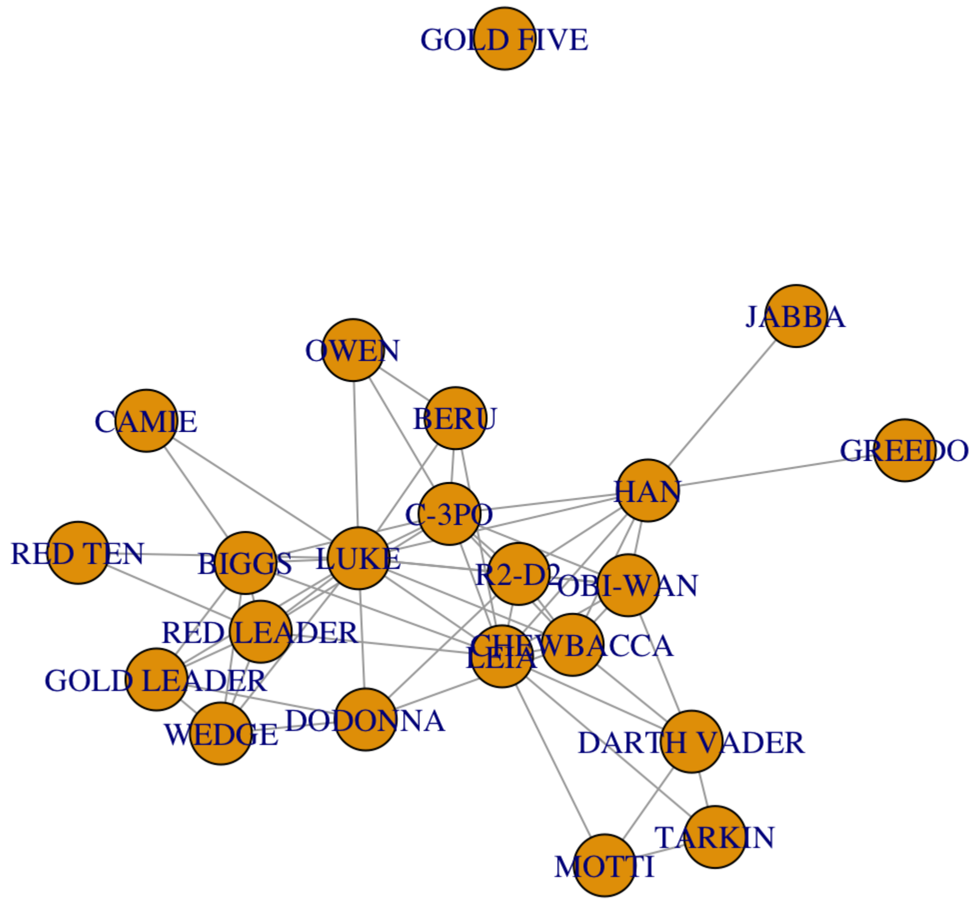
```
g[1,] # first row of adjacency matrix
```

```
##       R2-D2   CHEWBACCA       C-3PO        LUKE DARTH VADER       CAMIE
##           0           3          17          13           0           0
##       BIGGS        LEIA        BERU        OWEN     OBI-WAN       MOTTI
##           0           5           0           0           6           0
##      TARKIN         HAN      GREEDO       JABBA     DODONNA GOLD LEADER
##           0           5           0           0           1           0
##       WEDGE  RED LEADER     RED TEN   GOLD FIVE
##           0           0           0           0
```

Network visualization

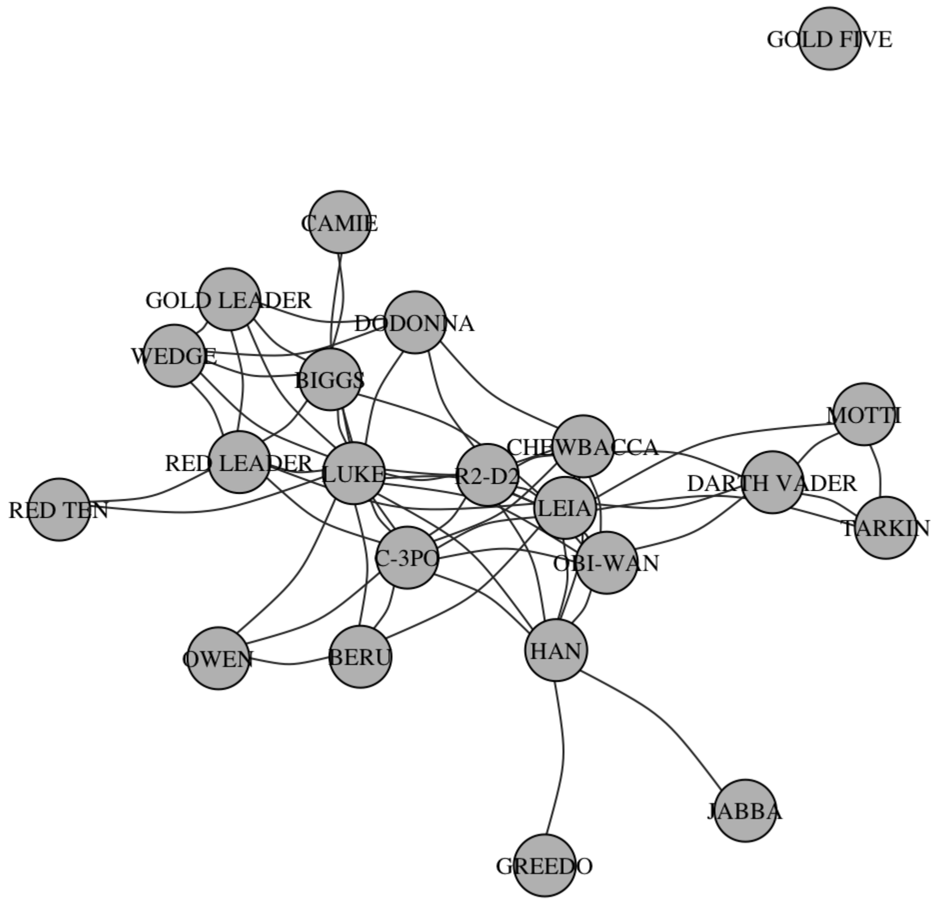
How can we visualize this network? The `plot()` function works out of the box, but the default options are often not ideal:

```
par(mar=c(0,0,0,0))
plot(g)
```



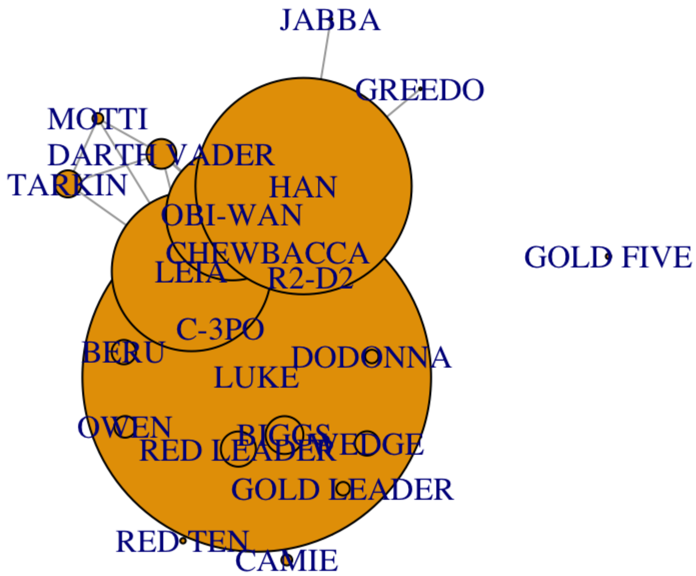
Let's see how we can improve this figure. To see all the available plotting options, you can check `?igraph.plotting` . Let's start by fixing some of these.

```
par(mar=c(0,0,0,0))
plot(g,
     vertex.color = "grey", # change color of nodes
     vertex.label.color = "black", # change color of labels
     vertex.label.cex = .75, # change size of labels to 75% of original size
     edge.curved=.25, # add a 25% curve to the edges
     edge.color="grey20") # change edge color to grey
```

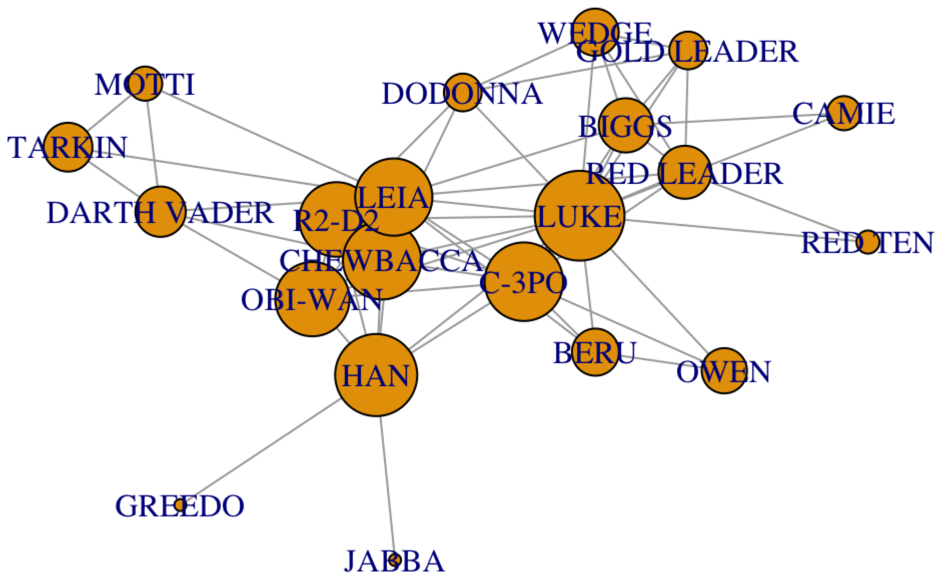


Now imagine that we want to modify some of these plotting attributes so that they are function of network properties. For example, a common adjustment is to change the size of the nodes and node labels so that they match their `importance` (we'll come back to how to measure that later). Here, `strength` will correspond to the number of scenes they appear in. And we're only going to show the labels of character that appear in 10 or more scenes.

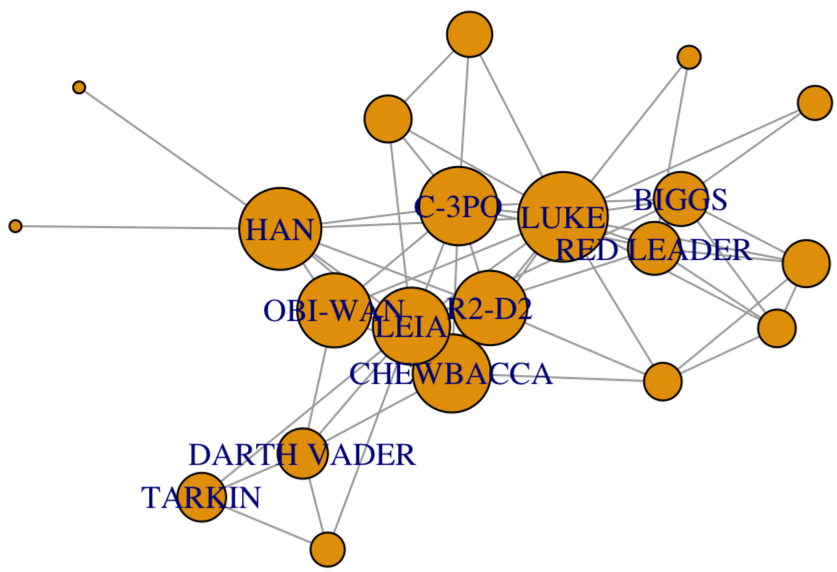
```
V(g)$size <- strength(g)
par(mar=c(0,0,0,0)); plot(g)
```




```
# taking the log to improve it
V(g)$size <- log(strength(g)) * 4 + 3
par(mar=c(0,0,0,0)); plot(g)
```




```
V(g)$label <- ifelse( strength(g)>=10, V(g)$name, NA )
par(mar=c(0,0,0,0)); plot(g)
```




```
# what does `ifelse` do?
nodes$name=="R2-D2"
```

```
##  [1]  TRUE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [12] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

```
ifelse(nodes$name=="R2-D2", "yes", "no")
```

```
##  [1] "yes" "no"  "no"  "no"  "no"  "no"  "no"  "no"  "no"  "no"  "no"
## [12] "no"  "no"  "no"  "no"  "no"  "no"  "no"  "no"  "no"  "no"  "no"
```

```
ifelse(grepl("R", nodes$name), "yes", "no")
```

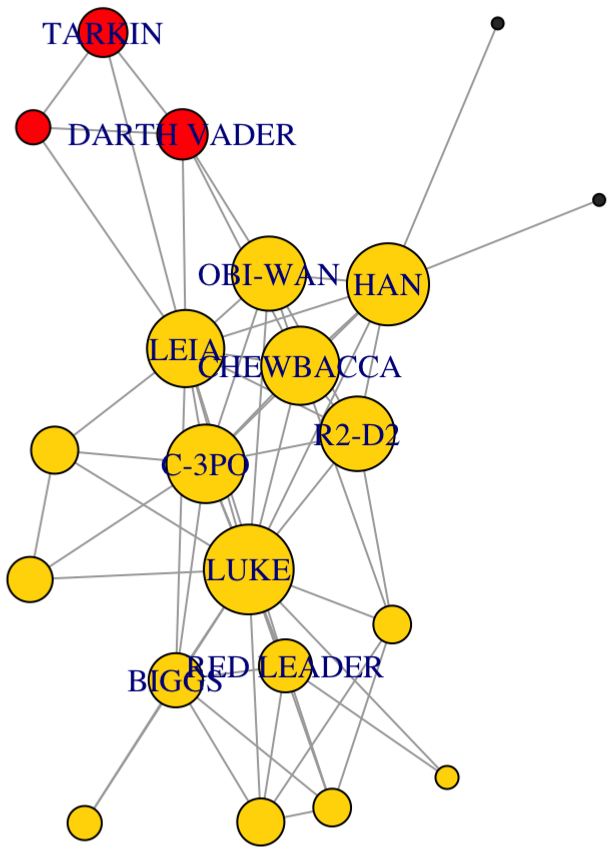
```
##  [1] "yes" "no"  "no"  "no"  "yes" "no"  "no"  "no"  "yes" "no"  "no"
## [12] "no"  "yes" "no"  "yes" "no"  "no"  "yes" "no"  "yes" "yes" "no"
```

We can also change the colors of each node based on what side they're in (dark side or light side).

```
# create vectors with characters in each side
dark_side <- c("DARTH VADER", "MOTTI", "TARKIN")
light_side <- c("R2-D2", "CHEWBACCA", "C-3PO", "LUKE", "CAMIE", "BIGGS",
                "LEIA", "BERU", "OWEN", "OBI-WAN", "HAN", "DODONNA",
                "GOLD LEADER", "WEDGE", "RED LEADER", "RED TEN", "GOLD FIVE")
other <- c("GREEDO", "JABBA")
# node we'll create a new color variable as a node property
V(g)$color <- NA
V(g)$color[V(g)$name %in% dark_side] <- "red"
V(g)$color[V(g)$name %in% light_side] <- "gold"
V(g)$color[V(g)$name %in% other] <- "grey20"
vertex_attr(g)
```

```
## $name
##  [1] "R2-D2"       "CHEWBACCA"   "C-3PO"       "LUKE"        "DARTH VADER"
##  [6] "CAMIE"       "BIGGS"       "LEIA"        "BERU"        "OWEN"
## [11] "OBI-WAN"     "MOTTI"       "TARKIN"      "HAN"         "GREEDO"
## [16] "JABBA"       "DODONNA"     "GOLD LEADER" "WEDGE"       "RED LEADER"
## [21] "RED TEN"     "GOLD FIVE"
##
## $id
##  [1]  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21
##
## $size
##  [1] 18.648092 19.572539 19.635532 22.439250 12.591581  8.545177 13.556229
##  [8] 19.310150 11.788898 11.317766 18.567281  8.545177 12.210340 20.528107
## [15]  3.000000  3.000000  9.437752  9.437752 11.788898 13.259797  5.772589
## [22]      -Inf
##
## $label
##  [1] "R2-D2"       "CHEWBACCA"   "C-3PO"       "LUKE"        "DARTH VADER"
##  [6] NA            "BIGGS"       "LEIA"        NA            NA
## [11] "OBI-WAN"     NA            "TARKIN"      "HAN"         NA
## [16] NA            NA            NA            NA            "RED LEADER"
## [21] NA            NA
##
## $color
##  [1] "gold"   "gold"   "gold"   "gold"   "red"    "gold"   "gold"
##  [8] "gold"   "gold"   "gold"   "gold"   "red"    "red"    "gold"
## [15] "grey20" "grey20" "gold"   "gold"   "gold"   "gold"   "gold"
## [22] "gold"
```

```
par(mar=c(0,0,0,0)); plot(g)
```




```
# what does %in% do?
1 %in% c(1,2,3,4)
```

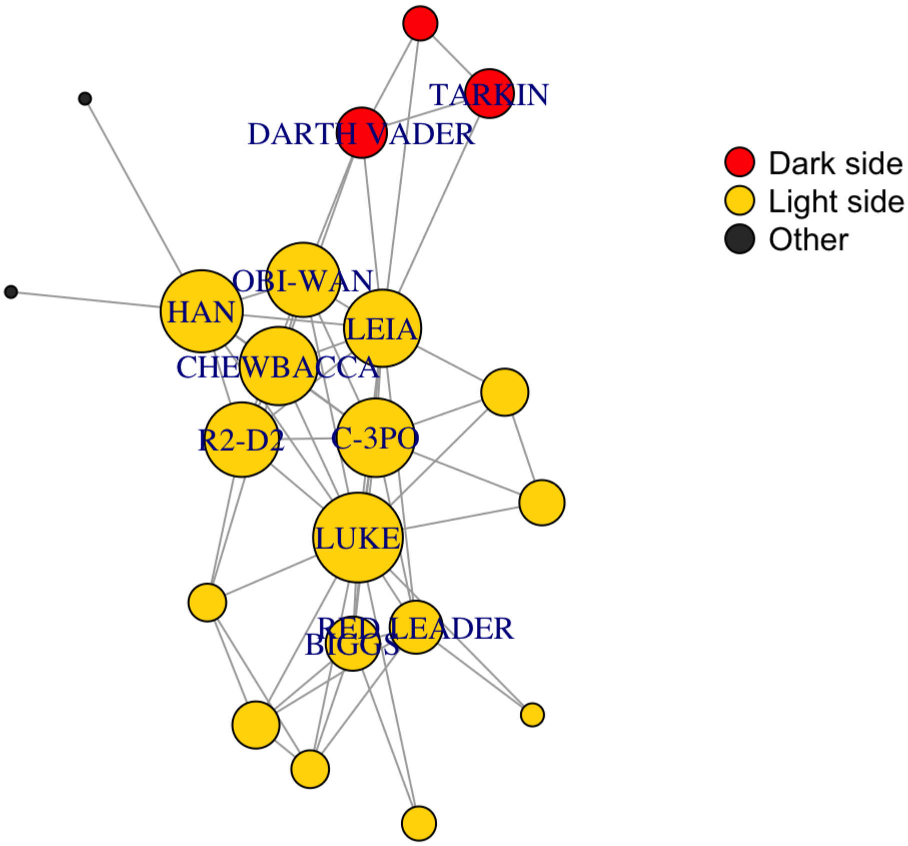
```
## [1] TRUE
```

```
1 %in% c(2,3,4)
```

```
## [1] FALSE
```

If we want to indicate what the colors correspond to, we can add a legend.

```
par(mar=c(0,0,0,0)); plot(g)
legend(x=.75, y=.75, legend=c("Dark side", "Light side", "Other"),
       pch=21, pt.bg=c("red", "gold", "grey20"), pt.cex=2, bty="n")
```

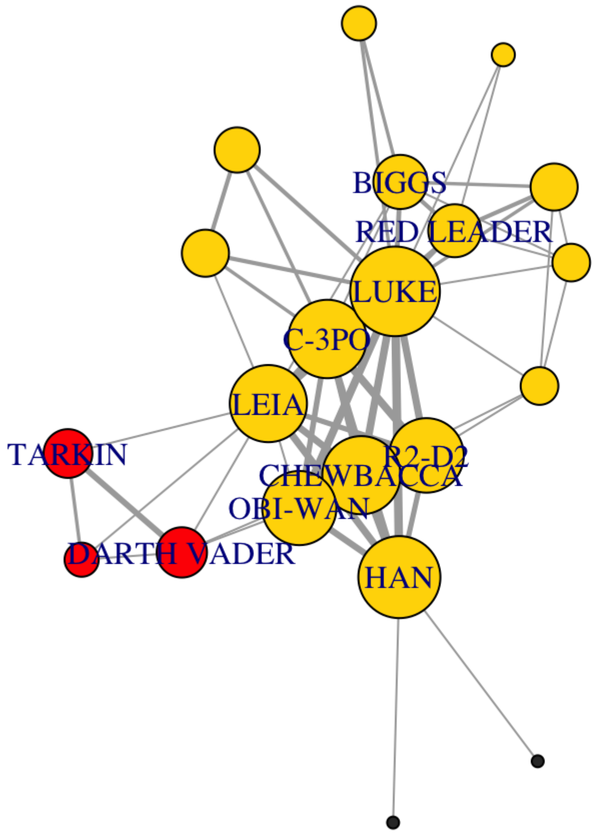


Edge properties can also be modified. For example, here the width of each edge is a function of the log number of scenes those two characters appear together.

```
E(g)$width <- log(E(g)$weight) + 1
edge_attr(g)
```

```
## $weight
##  [1] 17 13  6  5  5  3  1  7  5 16 19 11  1  1  2  2  4  1  3  3  2  3 18
## [24]  2  6 17  1 19  6  1  2  1  7  9 26  1  1  6  1  1 13  1  1  1  1  1
## [47]  1  2  1  1  3  3  1  1  3  1  2  1  1  1
## 
## $width
##  [1] 3.833213 3.564949 2.791759 2.609438 2.609438 2.098612 1.000000
##  [8] 2.945910 2.609438 3.772589 3.944439 3.397895 1.000000 1.000000
## [15] 1.693147 1.693147 2.386294 1.000000 2.098612 2.098612 1.693147
## [22] 2.098612 3.890372 1.693147 2.791759 3.833213 1.000000 3.944439
## [29] 2.791759 1.000000 1.693147 1.000000 2.945910 3.197225 4.258097
## [36] 1.000000 1.000000 2.791759 1.000000 1.000000 3.564949 1.000000
## [43] 1.000000 1.000000 1.000000 1.000000 1.000000 1.693147 1.000000
## [50] 1.000000 2.098612 2.098612 1.000000 1.000000 2.098612 1.000000
## [57] 1.693147 1.000000 1.000000 1.000000
```

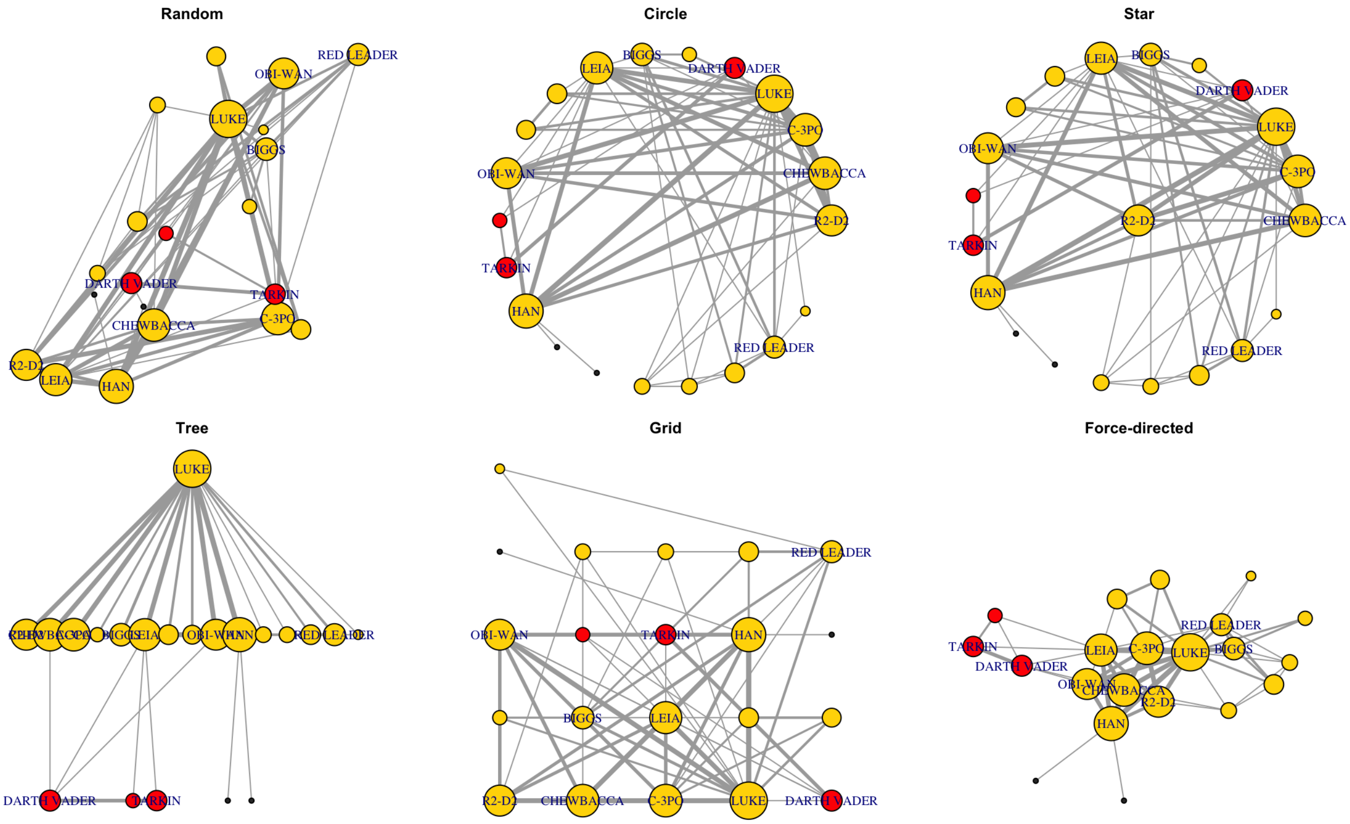
```
par(mar=c(0,0,0,0)); plot(g)
```



Up to now, each time we run the `plot` function, the nodes appear to be in a different location. Why? Because it's running a probabilistic function trying to locate them in the optimal way possible.

However, we can also specify the **layout** for the plot; that is, the (x,y) coordinates where each node will be placed. `igraph` has a few different layouts built-in, that will use different algorithms to find an `optimal` distribution of nodes. The following code illustrates some of these:

```
par(mfrow=c(2, 3), mar=c(0,0,1,0))
plot(g, layout=layout_randomly, main="Random")
plot(g, layout=layout_in_circle, main="Circle")
plot(g, layout=layout_as_star, main="Star")
plot(g, layout=layout_as_tree, main="Tree")
plot(g, layout=layout_on_grid, main="Grid")
plot(g, layout=layout_with_fr, main="Force-directed")
```



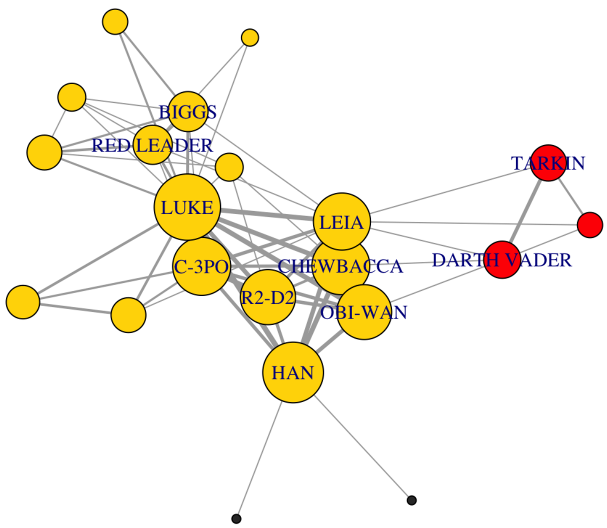
Note that each of these is actually just a matrix of (x,y) locations for each node.

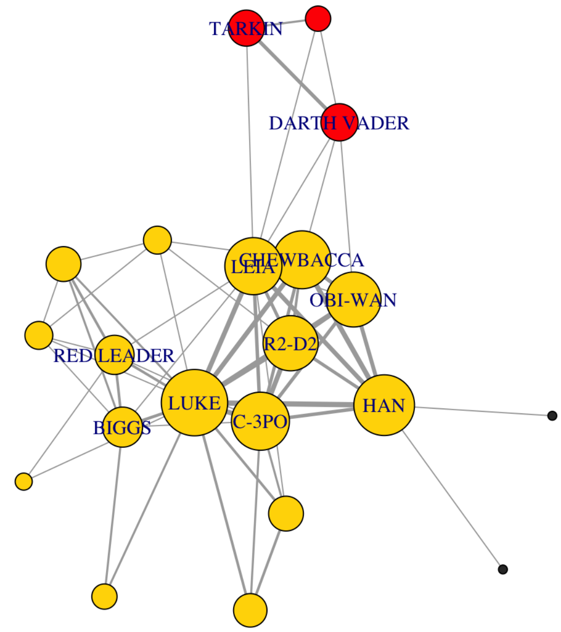
```
l <- layout_randomly(g)
str(l)
```

```
##  num [1:22, 1:2] -0.8468 -0.2524 0.1666 -0.0292 0.9343 ...
```

The most popular layouts are force-directed (https://en.wikipedia.org/wiki/Force-directed_graph_drawing). These algorithms, such as Fruchterman-Reingold, try to position the nodes so that the edges have similar length and there are as few crossing edges as possible. The idea is to generate “clean” layouts, where nodes that are closer to each other share more connections in common that those that are located further apart. Note that this is a non-deterministic algorithm: choosing a different seed will generate different layouts.

```
par(mfrow=c(1,2))
set.seed(777)
fr <- layout_with_fr(g, niter=1000)
par(mar=c(0,0,0,0)); plot(g, layout=fr)
set.seed(666)
fr <- layout_with_fr(g, niter=1000)
par(mar=c(0,0,0,0)); plot(g, layout=fr)
```


BIGGS
RED LEADER
LUKE
LEIA
TARKIN
C-3PO
CHEWBACCA
DARTH VADER
R2-D2
OBI-WAN
HAN


TARKIN
DARTH VADER
CHEWBACCA
LEIA
OBI-WAN
R2-D2
RED LEADER
LUKE
C-3PO
HAN
BIGGS