Network Analysis on Talent Flow Between Firms

This project explores LinkedIn-based talent movement among firms. We use network analysis to understand how employees flow between companies, identify key hubs, detect communities, and analyze network properties like assortativity and PageRank.

Load Required Libraries

```r
library(igraph)
```

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

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

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

```r
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:igraph':
##
##     as_data_frame, groups, union

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```r
library(readr)
```

Load and Prepare Data

```r
df_company <- read.csv("linkedin_company_metadata.csv")
df_talent_flows <- read.csv("talent_flows.csv")

# Extract edges for network graph construction
df_edges <- df_talent_flows %>% select(from, to)
head(df_edges)
```

```
##                  from                    to
## 1                at&t                oracle
## 2    colgate-palmolive                 nike
## 3 agilent-technologies              stryker
## 4                ebay               expedia
## 5             comcast republic-services-inc
## 6                 aon                   aig
```

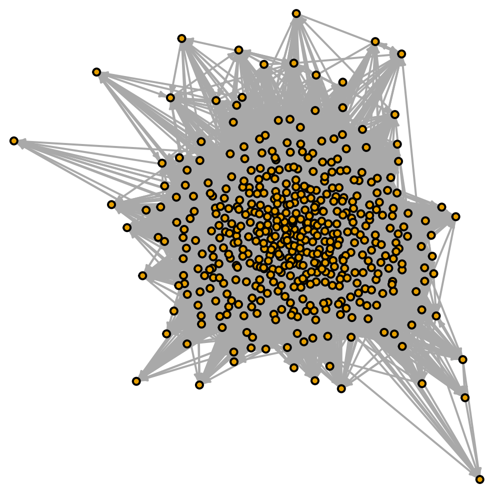
Construct Directed Graph

```
graph <- graph_from_data_frame(df_edges, directed = TRUE)
summary(graph)
```

```
## IGRAPH f954b6e DN-- 473 81114 --
## + attr: name (v/c)
```

```
plot(graph,
     vertex.label = NA,
     vertex.size = 3,
     edge.arrow.size = 0.2,
     main = "Overall Talent Flow Network")
```

Overall Talent Flow Network



Compute Degree Metrics

We examine in- and out-degrees to understand how firms attract or lose talent in the network.

```
in_degrees <- degree(graph, mode = "in")
out_degrees <- degree(graph, mode = "out")

# Top 10 firms by in-degree and out-degree
top_in_degrees <- sort(in_degrees, decreasing = TRUE)[1:10]
top_out_degrees <- sort(out_degrees, decreasing = TRUE)[1:10]

top_in_degrees
```

```
##                       ibm                  accenture
##                       417                        409
## hewlett-packard-enterprise                      at&t
##                       407                        406
##           bank-of-america                     amazon
##                       405                        405
##                wellsfargo             jpmorgan-chase
##                       404                        390
##                 microsoft                       citi
```

```
##                         390                        387
```

```
top_out_degrees
```

```
##                         ibm                       at&t
##                         440                        437
## hewlett-packard-enterprise             jpmorgan-chase
##                         432                        428
##             bank-of-america                  accenture
##                         426                        419
##                          ge                 wellsfargo
##                         417                        416
##                        citi                     target
##                         412                        411
```

Understanding In-Degree and Out-Degree in a Talent Flow Network

The computed **in-degree** reflects how often a firm is chosen as the next career step. A high in-degree suggests a firm is an attractive destination, often due to:

- Strong market reputation
- Growth opportunities
- Competitive employee benefits
- Strategic positioning within the industry

The **out-degree** metric, on the other hand, represents how many employees are leaving a firm for other firms. A high out-degree might indicate that a firm is:

- Undergoing organizational changes (e.g., restructuring or downsizing)
- A major source of talent development (feeding into other firms)
- Experiencing talent loss due to better offers elsewhere

Examples

- **High In-Degree Firms** (e.g., IBM, Accenture, Hewlett-Packard Enterprise):
  These companies attract a large number of incoming employees and are considered top destinations within the professional network.
- **High Out-Degree Firms** (e.g., IBM, AT&T, Hewlett-Packard Enterprise):
  These firms have significant talent outflow, which could reflect internal shifts, competitive poaching, or their role as training grounds.

Why Are High-Degree Firms Often Large Firms?

This aligns with earlier observations—firms with the highest degrees tend to be larger. Possible reasons include:

- **Larger Workforce**: Bigger firms have more employees, resulting in more natural inflow and outflow.
- **Diverse Opportunities**: A wider range of roles attracts a more diverse talent pool.
- **Stronger Brand Recognition**: Well-known firms are more desirable to job seekers.

- **Greater Market Visibility**: Large companies appear more often on job platforms and in professional networks.
- **More Recruitment Resources**: Bigger budgets allow for more effective hiring strategies.

  In summary:
  Firm size significantly impacts talent flow dynamics.
  Larger companies tend to attract and release more employees due to their visibility, scale, and organizational capacity.

Analyze Degree vs Firm Size via Linear Regression

We assess how firm size (employee count) impacts talent inflow/outflow.

```r
firm_data <- data.frame(name = V(graph)$name, in_degree = in_degrees, out_degree = out_degrees)
firm_data <- merge(firm_data, df_company, by.x = "name", by.y = "company_id")

model_in_degree <- lm(in_degree ~ emp_count, data = firm_data)
summary(model_in_degree)
```

```
##
## Call:
## lm(formula = in_degree ~ emp_count, data = firm_data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -456.46  -42.82   -3.25   47.08  143.81
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 1.366e+02  3.407e+00   40.11   <2e-16 ***
## emp_count   9.545e-04  4.365e-05   21.87   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 65.47 on 471 degrees of freedom
## Multiple R-squared:  0.5038, Adjusted R-squared:  0.5027
## F-statistic: 478.2 on 1 and 471 DF,  p-value: < 2.2e-16
```

```r
model_out_degree <- lm(out_degree ~ emp_count, data = firm_data)
summary(model_out_degree)
```

```
##
## Call:
## lm(formula = out_degree ~ emp_count, data = firm_data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -507.64  -49.69   -2.16   56.89  134.65
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 1.329e+02  3.684e+00   36.08   <2e-16 ***
## emp_count   1.055e-03  4.721e-05   22.36   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 70.81 on 471 degrees of freedom
## Multiple R-squared:  0.5148, Adjusted R-squared:  0.5138
## F-statistic: 499.8 on 1 and 471 DF,  p-value: < 2.2e-16
```

Linear Regression Results: Employee Count vs. In-/Out-Degree

To assess whether firm size (measured by employee count) influences talent movement, we ran two linear regressions:

- One with **in-degree** as the dependent variable
- One with **out-degree** as the dependent variable

In-Degree Model

- **Intercept**: ~136.6
  This is the expected in-degree when the employee count is zero. While theoretical (as firms can't actually have zero employees), it serves as a baseline for the model.
- **Coefficient for `emp_count`**: ~0.0009545
  Each additional employee is associated with an increase of approximately 0.00095 in in-degree, suggesting a positive relationship between firm size and in-degree.
- **P-values**:
  Both the intercept and the employee count coefficient are statistically significant ($p < 0.05$).
- **R-squared**: 0.504
  About 50.4% of the variation in in-degree is explained by employee count.

Out-Degree Model

- **Intercept**: ~132.9
  Represents the expected out-degree at zero employees (again, a theoretical value).
- **Coefficient for `emp_count`**: ~0.001055
  Each additional employee corresponds to an increase of approximately 0.00106 in out-degree, indicating a positive relationship.
- **P-values**:
  Both coefficients are statistically significant ($p < 0.05$).
- **R-squared**: 0.515
  About 51.5% of the variation in out-degree is explained by employee count.

Interpretation

Both models reveal a **statistically significant and positive relationship** between firm size and degree centrality:

- Larger firms tend to have **higher in-degrees** (receive more incoming talent) and **higher out-degrees** (send out more employees).
- The R-squared values around 50% indicate that employee count is an important factor, though not the only one.
- The effect is slightly stronger for **out-degree**, but both relationships are similar in strength.

These findings support the intuition that **larger firms play a central role in talent flow networks**, both as talent attractors and as sources of talent.

Add Weighted Edges Based on Migration per Employee

```
df_talent_flows_merged <- merge(df_talent_flows, df_company[, c('company_id', 'emp_count')],
                                by.x = 'from', by.y = 'company_id', all.x = TRUE)

df_talent_flows_merged$weight <- df_talent_flows_merged$migration_count / df_talent_flows_merged$emp_cou

df_edges_with_weight <- merge(df_edges, df_talent_flows_merged[, c('from', 'to', 'weight')],
                              by = c('from', 'to'), all.x = TRUE)

df_edges <- df_edges_with_weight
head(df_edges)
```

```
##   from         to       weight
## 1   3m    abbott- 8.342416e-04
## 2   3m     abbvie 5.382204e-05
## 3   3m    abiomed 2.691102e-05
## 4   3m  accenture 9.822522e-04
## 5   3m activision 2.691102e-05
## 6   3m        adm 5.382204e-05
```

Construct Weighted Graph

```
df_edges <- df_edges[, c("from", "to", "weight")]
str(df_edges)
```

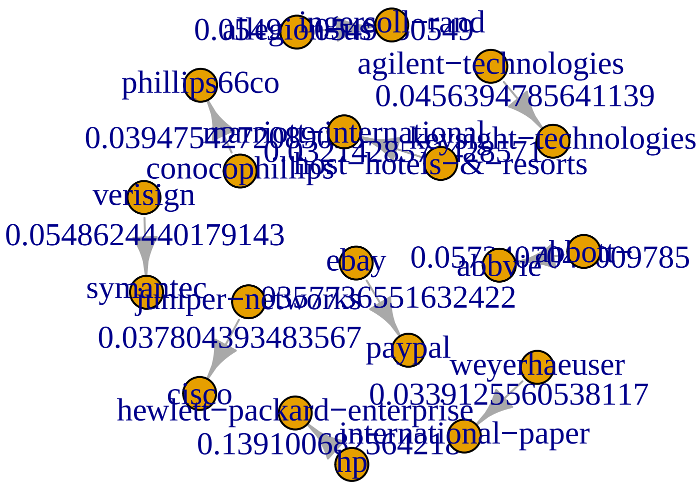
```
## 'data.frame':    81114 obs. of  3 variables:
##  $ from  : chr  "3m" "3m" "3m" "3m" ...
##  $ to    : chr  "abbott-" "abbvie" "abiomed" "accenture" ...
##  $ weight: num  8.34e-04 5.38e-05 2.69e-05 9.82e-04 2.69e-05 ...
```

```
graph_df_edges <- graph_from_data_frame(df_edges, directed = TRUE)
summary(graph_df_edges)
```

```
## IGRAPH bde1cc7 DNW- 473 81114 --
## + attr: name (v/c), weight (e/n)
```

Visualize Top-Weighted Talent Flows

```
top_edges <- head(df_edges[order(-df_edges$weight), ], 10)
g_top_edges <- graph_from_data_frame(top_edges, directed = TRUE)

plot(g_top_edges, edge.label = E(g_top_edges)$weight)
```



Network Metrics on Top Edges

```r
cat("Number of Nodes:", vcount(g_top_edges), "\n")
```

```
## Number of Nodes: 20
```

```r
cat("Number of Edges:", ecount(g_top_edges), "\n")
```

```
## Number of Edges: 10
```

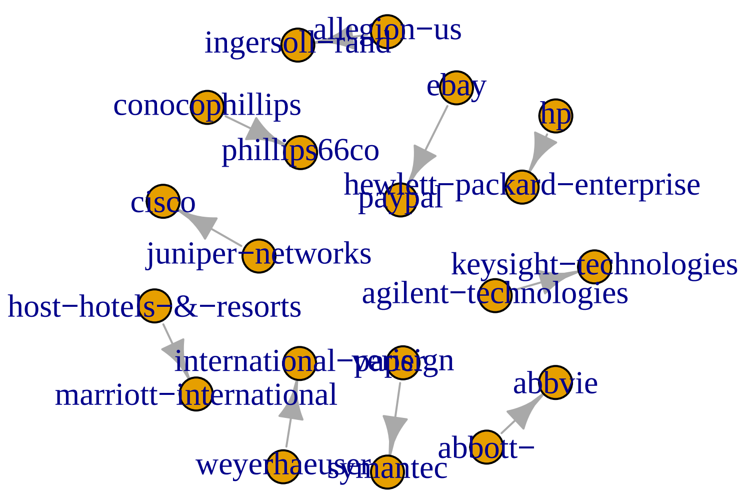
```r
degree_distribution <- degree(g_top_edges, mode = "all")
cat("Degree Centrality:", degree_distribution, "\n")
```

```
## Degree Centrality: 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

```r
betweenness_distribution <- betweenness(g_top_edges)
cat("Betweenness Centrality:", betweenness_distribution, "\n")
```

```
## Betweenness Centrality: 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

```r
plot(g_top_edges)
```



Interpreting High-Weight Edges in the Talent Flow Network

In this network, an edge's **weight** represents the proportion of employees moving from one firm (`from`) to another (`to`), relative to the size of the source firm.
A **high-weight edge** indicates a notably strong talent flow between two firms.

What Do High Weights Suggest?

- **High Employee Turnover**: The source firm may be experiencing internal change, dissatisfaction, or talent poaching.
- **Attractive Destinations**: Destination firms may offer better career prospects, higher compensation, or stronger employer branding.
- **Industry Trends**: High-weight edges within the same industry may reflect strong sector-specific mobility.

Notable Observations from the Graph

- **Spin-Offs and Restructuring**: Some connections link firms with historical ties, suggesting transitional movement after corporate restructuring.
- **Competitive Hiring**: Edges between direct competitors may indicate aggressive talent acquisition or career-driven switches.
- **Cross-Sector Mobility**: Movement across industries may signal broader economic shifts or emerging talent needs.

Summary

High-weight edges reveal meaningful dynamics in the job market—identifying firms that are central hubs of talent movement.
These patterns offer insight into employee behavior, firm reputation, and industry evolution.

For deeper understanding, further qualitative analysis may be needed, such as reviewing external factors like market conditions or firm-level strategies.

Understanding PageRank and the Random Surfer Model

The **PageRank** algorithm ranks the importance of nodes in a network based on the idea of a *random surfer*.

The Intuition

Imagine a person randomly clicking through links on a website (or navigating a network of firms).
Each time they arrive at a node, they randomly select an outgoing edge to follow.

- The **more frequently** a node is visited during this process, the **higher its PageRank**.
- The algorithm captures the idea that **important nodes are likely to be visited more often**.

Unweighted vs. Weighted Networks

- In an **unweighted graph**, the surfer has an **equal probability** of choosing any of the outgoing edges from a node.
- In a **weighted graph**, the surfer is **more likely to follow edges with higher weights**.

> This means that in weighted networks, transitions are **biased toward stronger or more significant connections**.

As a result, nodes connected by high-weight edges are more influential, and the PageRank distribution becomes more concentrated around those nodes.

This weighted approach better captures real-world dynamics—such as employee flows between firms—where not all connections are equally likely or important.

PageRank: Unweighted vs Weighted

```r
pr_unweighted <- page_rank(graph_df_edges, algo="prpack", weights = NA)
pr_weighted <- page_rank(graph_df_edges, algo="prpack", weights = E(graph_df_edges)$weight)

top_nodes_unweighted <- head(sort(pr_unweighted$vector, decreasing = TRUE), 10)
top_nodes_weighted <- head(sort(pr_weighted$vector, decreasing = TRUE), 10)

top_nodes_unweighted
```

```
##                wellsfargo                       ibm
##               0.005052306               0.005042449
##                 accenture           bank-of-america
##               0.004941054               0.004872047
##                      at&t hewlett-packard-enterprise
##               0.004823967               0.004822008
##                    amazon            jpmorgan-chase
##               0.004773077               0.004701858
##                 microsoft                      citi
##               0.004629907               0.004615667
```

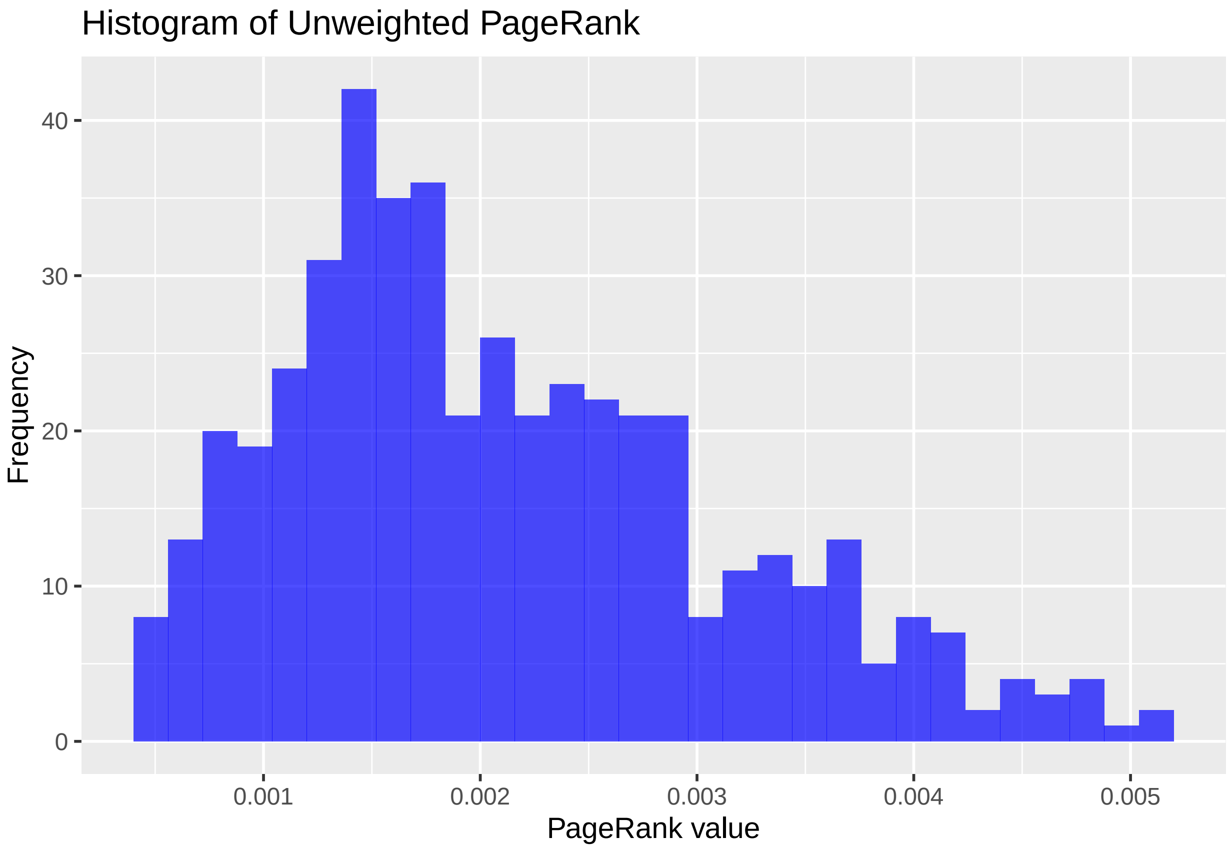
```r
top_nodes_weighted
```

```
##                       ibm                 microsoft
##                0.02584084                0.02254956
## hewlett-packard-enterprise               wellsfargo
##                0.02095859                0.02031841
##           bank-of-america            jpmorgan-chase
##                0.01918484                0.01867777
##                      citi                 accenture
##                0.01614856                0.01609669
##                    google                    oracle
##                0.01494275                0.01332736
```

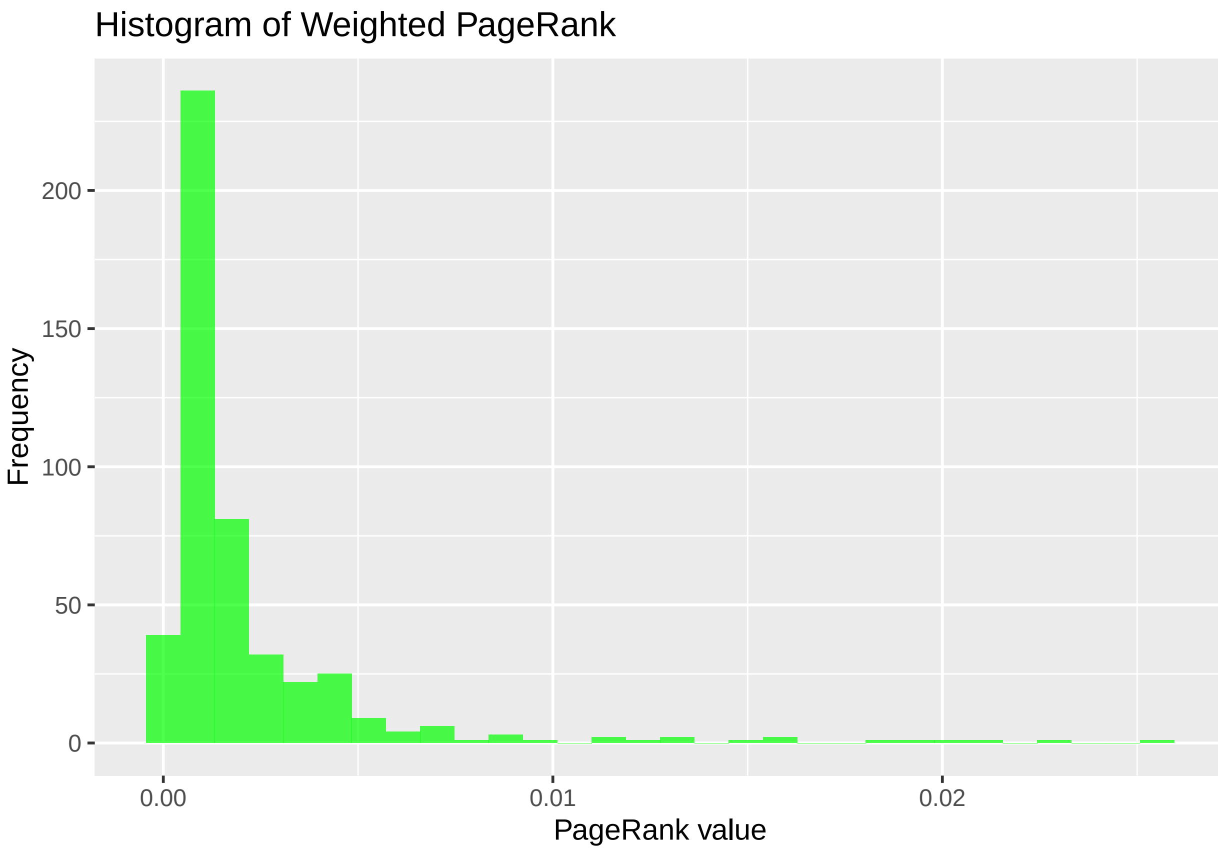
Visualize PageRank Distributions

```r
library(ggplot2)

df_unweighted <- data.frame(PageRank = pr_unweighted$vector)
df_weighted <- data.frame(PageRank = pr_weighted$vector)

ggplot(df_unweighted, aes(x = PageRank)) +
  geom_histogram(bins = 30, fill = 'blue', alpha = 0.7) +
  labs(title = "Histogram of Unweighted PageRank",
```

```
      x = "PageRank value",
      y = "Frequency")
```




```
ggplot(df_weighted, aes(x = PageRank)) +
  geom_histogram(bins = 30, fill = 'green', alpha = 0.7) +
  labs(title = "Histogram of Weighted PageRank",
       x = "PageRank value",
       y = "Frequency")
```



The significant difference in distributions shows that the edge weights have a major impact on the importance of nodes in the network. Nodes with high-weight inbound edges are considered much more important in the weighted PageRank algorithm.

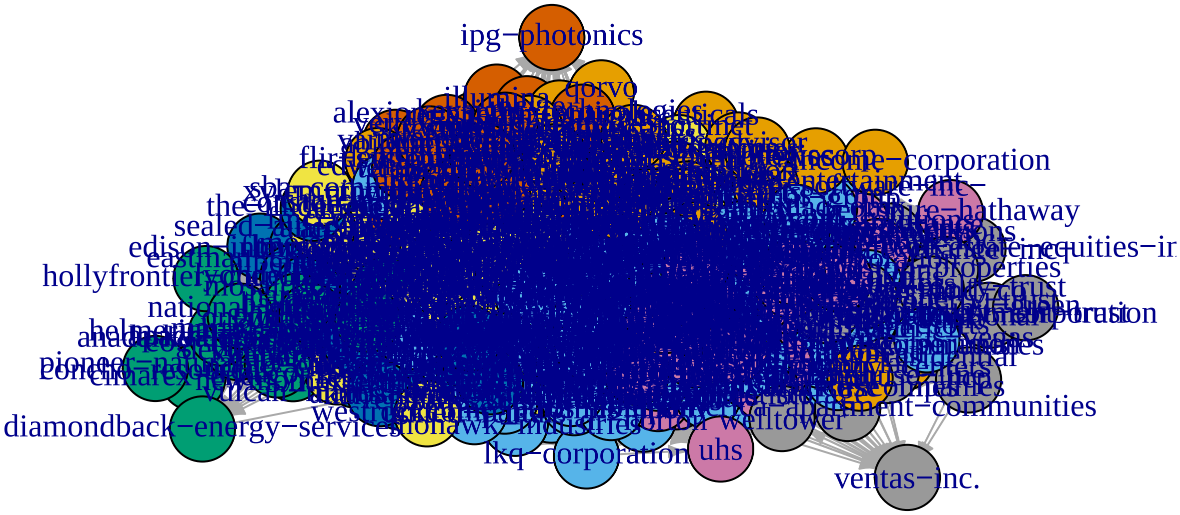
The key difference between the two calculations is that the weighted PageRank takes into account the 'strength' or 'significance' of the connections between nodes, while the unweighted PageRank does not. As a result, in the weighted PageRank, nodes that are connected by edges with higher weights will have their importance exaggerated compared to those with lower-weighted connections. This often leads to a more polarized distribution where a few nodes have much higher importance scores than the rest.

Detect Communities with Walktrap Algorithm

```
wt_communities <- walktrap.community(graph_df_edges, steps = 4)
membership <- membership(wt_communities)
sizes(wt_communities)
```

```
## Community sizes
##   1   2   3   4   5   6   7   8   9  10
##  64 120  25  80  46  39  74  17   5   3
```

```
plot(graph_df_edges, vertex.color = membership(wt_communities), asp = FALSE, edge.arrow.size = 0.5)
```



Explore Community Characteristics

```
membership_vector <- as.numeric(membership(wt_communities))
company_names <- V(graph_df_edges)$name

community_data <- data.frame(company_id = company_names, community = membership_vector)
extended_community_data <- merge(community_data, df_company, by = "company_id")

for(i in unique(extended_community_data$community)) {
  cat("Community", i, ":\n")
  community_subset <- subset(extended_community_data, community == i, select = c(company_id, community,
  print(community_subset)
  cat("\n\n")
}
```

```
## Community 4 :
##                          company_id community
## 1                                3m         4
## 7                               adm         4
## 20                            alcoa         4
## 24                      allegion-us         4
## 29                           altria         4
## 39                 amerisourcebergen         4
## 40                           ametek         4
## 57                   avery-dennison         4
## 59                             ball         4
## 70                       borgwarner         4
## 76                     brown-forman         4
## 80              campbell-soup-company         4
## 82                   cardinal-health         4
## 85                   caterpillar-inc         4
## 101              church-&-dwight-co-inc         4
## 111                  colgate-palmolive         4
## 117               constellation-brands         4
## 120               corning-incorporated         4
## 122                              coty         4
## 125                        cummins-inc         4
```

```
## 127                          danaher         4
## 141                        dovercorp         4
## 148                 eaton-corporation         4
## 150                           ecolab         4
## 155                          emerson         4
## 186                ford-motor-company         4
## 194                               ge         4
## 196                     general-mills         4
## 197                    general-motors         4
## 205                  hanesbrands-inc-         4
## 206     harley-davidson-motor-company         4
## 208                           hasbro         4
## 212                      henry-schein         4
## 218                         honeywell         4
## 219                      hormel-foods         4
## 225               idexx-laboratories         4
## 226                              iff         4
## 231                     ingersoll-rand         4
## 232                         insidepmi         4
## 235               international-paper         4
## 242                              itw         4
## 247                        john-deere         4
## 249                  johnson-controls         4
## 253                   kellogg-company         4
## 256                    kimberly-clark         4
## 262                           labcorp         4
## 280                 masco-corporation         4
## 282                            mattel         4
## 284                         mccormick         4
## 297                      molson-coors         4
## 298             mondelezinternational         4
## 299                  monster-energy_2         4
## 311                      newellbrands         4
## 315                           nielsen         4
## 316                              nike         4
## 332                   parker-hannifin         4
## 335                               pca         4
## 336                           pentair         4
## 338                           pepsico         4
## 345                    ppg-industries         4
## 349                  procter-&-gamble         4
## 370               rockwell-automation         4
## 378            sealed-air-corporation         4
## 384                     snap-on-tools         4
## 388          stanley-black-decker-inc         4
## 396                             sysco         4
## 400                   te-connectivity         4
## 403                           textron         4
## 405                the-clorox-company         4
## 406             the-coca-cola-company         4
## 407 the-estee-lauder-companies-inc-         4
## 409               the-hershey-company         4
## 411          the-j-m--smucker-company         4
## 412            the-kraft-heinz-company         4
```

```
## 432            united-technologies         4
## 444                 vf-corporation         4
## 460                westrockcompany         4
## 461                   weyerhaeuser         4
## 462          whirlpool-corporation         4
## 469                      xylem-inc-         4
##                                  industry
## 1   mechanical or industrial engineering
## 7                        food production
## 20                       mining & metals
## 24   electrical/electronic manufacturing
## 29                         consumer goods
## 39                  hospital & health care
## 40   electrical/electronic manufacturing
## 57                packaging and containers
## 59                packaging and containers
## 70                              automotive
## 76                        wine and spirits
## 80                        food & beverages
## 82                  hospital & health care
## 85                               machinery
## 101                         consumer goods
## 111                         consumer goods
## 117                       wine and spirits
## 120          glass, ceramics & concrete
## 122                              cosmetics
## 125                             automotive
## 127  electrical/electronic manufacturing
## 141                              machinery
## 148  electrical/electronic manufacturing
## 150                              chemicals
## 155 mechanical or industrial engineering
## 186                             automotive
## 194  electrical/electronic manufacturing
## 196                         consumer goods
## 197                             automotive
## 205                         consumer goods
## 206                             automotive
## 208                         consumer goods
## 212                        medical devices
## 218  electrical/electronic manufacturing
## 219                         consumer goods
## 225                          biotechnology
## 226                              chemicals
## 231  electrical/electronic manufacturing
## 232                                tobacco
## 235                 paper & forest products
## 242                              machinery
## 247                              machinery
## 249 mechanical or industrial engineering
## 253                         consumer goods
## 256                         consumer goods
## 262                  hospital & health care
## 280                     building materials
```

```
## 282                     consumer goods
## 284                    food production
## 297                  food & beverages
## 298                    food production
## 299                  food & beverages
## 311                     consumer goods
## 315               information services
## 316                     sporting goods
## 332 mechanical or industrial engineering
## 335             packaging and containers
## 336 mechanical or industrial engineering
## 338                  food & beverages
## 345                          chemicals
## 349                     consumer goods
## 370              industrial automation
## 378             packaging and containers
## 384                         automotive
## 388                     consumer goods
## 396                  food & beverages
## 400  electrical/electronic manufacturing
## 403                aviation & aerospace
## 405                     consumer goods
## 406                  food & beverages
## 407                          cosmetics
## 409                     consumer goods
## 411                     consumer goods
## 412                  food & beverages
## 432                aviation & aerospace
## 444                  apparel & fashion
## 460             packaging and containers
## 461              paper & forest products
## 462                     consumer goods
## 469 mechanical or industrial engineering
##
##
## Community 6 :
##                   company_id community                         industry
## 2                    abbott-         6         hospital & health care
## 3                     abbvie         6                pharmaceuticals
## 4                    abiomed         6                medical devices
## 22    alexion-pharmaceuticals         6                  biotechnology
## 25                  allergan         6                pharmaceuticals
## 41                     amgen         6                  biotechnology
## 61          baxter-healthcare         6                medical devices
## 63                       bd1         6                medical devices
## 66                   biogen-         6                  biotechnology
## 72          boston-scientific         6                medical devices
## 73       bristol-myers-squibb         6                pharmaceuticals
## 90                   celgene         6                pharmaceuticals
## 131            dentsplysirona         6                medical devices
## 152       edwards-lifesciences         6                medical devices
## 154      eli-lilly-and-company         6                  biotechnology
## 199            gilead-sciences         6                  biotechnology
## 217                   hologic         6                medical devices
```

```
## 228                  illumina         6                        biotechnology
## 229               ims-health         6             hospital & health care
## 230                   incyte         6                     pharmaceuticals
## 237        intuitive-surgical         6                     medical devices
## 240             ipg-photonics         6 electrical/electronic manufacturing
## 248         johnson-&-johnson         6             hospital & health care
## 287                 medtronic         6                     medical devices
## 288                     merck         6                     pharmaceuticals
## 305                     mylan         6                     pharmaceuticals
## 308       nektar-therapeutics         6                     pharmaceuticals
## 339               perkinelmer         6                        biotechnology
## 340                   perrigo         6                     pharmaceuticals
## 341                    pfizer         6                     pharmaceuticals
## 365 regeneron-pharmaceuticals         6                        biotechnology
## 368                    resmed         6                     medical devices
## 391                   stryker         6                     medical devices
## 401                  teleflex         6                     medical devices
## 415  thermo-fisher-scientific         6                             research
## 443    vertex-pharmaceuticals         6                        biotechnology
## 453                    waters         6                             research
## 471              zimmerbiomet         6                     medical devices
## 473                    zoetis         6                     pharmaceuticals
##
##
## Community 2 :
##                          company_id community
## 5                         accenture         2
## 9                               adp         2
## 10               advance-auto-parts         2
## 12                            aflac         2
## 18                  alaska-airlines         2
## 33                american-airlines         2
## 35                 american-express         2
## 36                   american-tower         2
## 37                   american-water         2
## 52                             at&t         2
## 55                         autozone         2
## 65                         best-buy         2
## 69                           boeing         2
## 77                     c-h-robinson         2
## 83                           carmax         2
## 88                          cbs-com         2
## 93                      centurylink         2
## 94               cerner-corporation         2
## 97           charter-communications         2
## 99           chipotle-mexican-grill         2
## 104                          cintas         2
## 110                       cognizant         2
## 112                         comcast         2
## 119                          copart         2
## 121                costco-wholesale         2
## 123                    crown-castle         2
## 124              csx-transportation         2
## 126                      cvs-health         2
```

```
## 128            darden-restaurants         2
## 129                        davita         2
## 130               delta-air-lines         2
## 136      discovery-communications         2
## 137                   dish-network         2
## 138                dollar-general         2
## 139            dollar-tree-stores         2
## 143                     dr-horton         2
## 158                       equifax         2
## 167                    expeditors         2
## 168           extra-space-storage         2
## 172                      fastenal         2
## 174                         fedex         2
## 180                      fleetcor         2
## 185                   foot-locker         2
## 188      fox-filmed-entertainment         2
## 191                      gap-inc-         2
## 195              general-dynamics         2
## 198         genuine-parts-company         2
## 203                     h&r-block         2
## 207            harris-corporation         2
## 215              hilton-worldwide         2
## 220         host-hotels-&-resorts         2
## 224                           ibm         2
## 239                           ipg         2
## 241                 iron-mountain         2
## 243       jack-henry-&-associates         2
## 245 jb-hunt-transport-services-inc         2
## 252   kansas-city-southern-railway         2
## 260       kohls-department-stores         2
## 261                        kroger         2
## 264               leggett-&-platt         2
## 265                        lennar         2
## 266                limited-brands         2
## 268               lkq-corporation         2
## 269               lockheed-martin         2
## 270     lowe%27s-home-improvement         2
## 274                          macy         2
## 277        marriott-international         2
## 281                    mastercard         2
## 285      mcdonald%27s-corporation         2
## 286                      mckesson         2
## 290     mgm-resorts-international         2
## 291                  michael-kors         2
## 296             mohawk-industries         2
## 306                    nasdaq-omx         2
## 319                     nordstrom         2
## 320              norfolk-southern         2
## 322   northrop-grumman-corporation         2
## 327         o%27reilly-auto-parts         2
## 331                        paccar         2
## 333                       paychex         2
## 347                 priceline-com         2
## 354                public-storage         2
```

```
## 355                  pultegroup        2
## 356                         pvh        2
## 359                ralph-lauren        2
## 361                    raytheon        2
## 367        republic-services-inc        2
## 369    robert-half-international        2
## 371                rollins-inc.        2
## 372                 ross-stores        2
## 375          sba-communications        2
## 379               sempra-energy        2
## 380            sherwin-williams        2
## 386          southwest-airlines        2
## 387                    spglobal        2
## 389                   starbucks        2
## 399                      target        2
## 410              the-home-depot        2
## 414      the-walt-disney-company        2
## 416              tiffany-and-co        2
## 417                         tjx        2
## 419       tractor-supply-company        2
## 422                        tsys        2
## 424                 tyson-foods        2
## 427                        ulta        2
## 428                under-armour        2
## 429                unionpacific        2
## 430             united-airlines        2
## 431              united-rentals        2
## 435                         ups        2
## 442                     verizon        2
## 445                      viacom        2
## 449                w.w.-grainger        2
## 450                   walgreens        2
## 451                     walmart        2
## 452            waste-management        2
## 459               western-union        2
## 465              wynn-las-vegas        2
## 470                   yum-brands        2
## 467                       xerox        2
##                              industry
## 5   information technology and services
## 9                     human resources
## 10                             retail
## 12                          insurance
## 18                 airlines/aviation
## 33                 airlines/aviation
## 35                financial services
## 36                telecommunications
## 37                          utilities
## 52                telecommunications
## 55                             retail
## 65                             retail
## 69               aviation & aerospace
## 77         logistics and supply chain
## 83                             retail
```

```
## 88                        entertainment
## 93  information technology and services
## 94  information technology and services
## 97                   telecommunications
## 99                          restaurants
## 104                 facilities services
## 110 information technology and services
## 112                    media production
## 119                          automotive
## 121                              retail
## 123                  telecommunications
## 124    transportation/trucking/railroad
## 126              hospital & health care
## 128                         restaurants
## 129              hospital & health care
## 130                   airlines/aviation
## 136                       entertainment
## 137                  telecommunications
## 138                              retail
## 139                              retail
## 143                        construction
## 158                  financial services
## 167          logistics and supply chain
## 168                         real estate
## 172                           wholesale
## 174            package/freight delivery
## 180                  financial services
## 185                              retail
## 188                       entertainment
## 191                              retail
## 195                     defense & space
## 198                          automotive
## 203                              retail
## 207                     defense & space
## 215                         hospitality
## 220                         real estate
## 224 information technology and services
## 239           marketing and advertising
## 241 information technology and services
## 243                   computer software
## 245    transportation/trucking/railroad
## 252    transportation/trucking/railroad
## 260                              retail
## 261                              retail
## 264                           furniture
## 265                         real estate
## 266                              retail
## 268                          automotive
## 269                     defense & space
## 270                              retail
## 274                              retail
## 277                         hospitality
## 281 information technology and services
## 285                         restaurants
```

```
## 286              hospital & health care
## 290                         hospitality
## 291                    apparel & fashion
## 296                            textiles
## 306                  financial services
## 319                              retail
## 320    transportation/trucking/railroad
## 322                     defense & space
## 327                              retail
## 331                          automotive
## 333                     human resources
## 347                            internet
## 354                         real estate
## 355                        construction
## 356                   apparel & fashion
## 359                   apparel & fashion
## 361                     defense & space
## 367              environmental services
## 369             staffing and recruiting
## 371                   consumer services
## 372                              retail
## 375                  telecommunications
## 379                           utilities
## 380                           chemicals
## 386                   airlines/aviation
## 387                information services
## 389                              retail
## 399                              retail
## 410                              retail
## 414                       entertainment
## 416              luxury goods & jewelry
## 417                              retail
## 419                              retail
## 422                  financial services
## 424                     food production
## 427                              retail
## 428                   apparel & fashion
## 429    transportation/trucking/railroad
## 430                   airlines/aviation
## 431                        construction
## 435    transportation/trucking/railroad
## 442 information technology and services
## 445                       entertainment
## 449     business supplies and equipment
## 450                              retail
## 451                              retail
## 452              environmental services
## 459                  financial services
## 465                         hospitality
## 467 information technology and services
## 470                         restaurants
##
##
## Community 1 :
```

```
##                       company_id community
## 6                     activision         1
## 8                          adobe         1
## 13         agilent-technologies          1
## 17          akamai-technologies          1
## 23             align-technology          1
## 30                        amazon         1
## 31                           amd         1
## 43               analog-devices          1
## 44                    ansys-inc          1
## 48                         apple         1
## 49            applied-materials          1
## 54                      autodesk         1
## 74                      broadcom         1
## 79       cadence-design-systems          1
## 105                        cisco         1
## 108                       citrix         1
## 149                         ebay         1
## 153              electronic-arts         1
## 159                      equinix         1
## 166                      expedia         1
## 170                  f5-networks         1
## 171                     facebook         1
## 181                 flir-systems         1
## 187                     fortinet         1
## 192          garmin-international        1
## 193                      gartner         1
## 202                       google         1
## 214  hewlett-packard-enterprise          1
## 221                           hp         1
## 233            intel-corporation         1
## 236                       intuit         1
## 251              juniper-networks        1
## 255       keysight-technologies          1
## 259                   kla-tencor         1
## 263                 lam-research         1
## 283              maxim-integrated        1
## 292          microchip-technology        1
## 293            micron-technology         1
## 294                    microsoft         1
## 303            motorolasolutions         1
## 309                       netapp         1
## 310                      netflix         1
## 313                     newscorp         1
## 326                       nvidia         1
## 329                       oracle         1
## 334                       paypal         1
## 357                        qorvo         1
## 358                     qualcomm         1
## 362    realty-income-corporation         1
## 363                      red-hat         1
## 374                   salesforce         1
## 377           seagate-technology         1
## 382        skyworks-solutions-inc        1
```

```
## 393               svb-financial-group         1
## 394                          symantec         1
## 398 take-2-interactive-software-inc-         1
## 402                 texas-instruments         1
## 421                       tripadvisor         1
## 423                           twitter         1
## 438            varian-medical-systems         1
## 440                          verisign         1
## 446                              visa         1
## 458                   western-digital         1
## 468                            xilinx         1
##                                industry
## 6                        computer games
## 8                     computer software
## 13                        biotechnology
## 17                             internet
## 23                      medical devices
## 30                             internet
## 31                       semiconductors
## 43                       semiconductors
## 44                    computer software
## 48                 consumer electronics
## 49                       semiconductors
## 54                    computer software
## 74                       semiconductors
## 79                    computer software
## 105                 computer networking
## 108                   computer software
## 149                            internet
## 153                       entertainment
## 159                            internet
## 166                            internet
## 170                 computer networking
## 171                            internet
## 181 electrical/electronic manufacturing
## 187         computer & network security
## 192                consumer electronics
## 193 information technology and services
## 202                            internet
## 214 information technology and services
## 221 information technology and services
## 233                      semiconductors
## 236                   computer software
## 251                 computer networking
## 255 electrical/electronic manufacturing
## 259                      semiconductors
## 263                      semiconductors
## 283                      semiconductors
## 292                      semiconductors
## 293                      semiconductors
## 294                   computer software
## 303                  telecommunications
## 309 information technology and services
## 310                       entertainment
```

```
## 313                       online media
## 326                  computer hardware
## 329 information technology and services
## 334                           internet
## 357                     semiconductors
## 358                           wireless
## 362                        real estate
## 363                  computer software
## 374                           internet
## 377                  computer hardware
## 382                     semiconductors
## 393                 financial services
## 394                  computer software
## 398                      entertainment
## 402                     semiconductors
## 421                           internet
## 423                           internet
## 438                    medical devices
## 440 information technology and services
## 446 information technology and services
## 458                  computer hardware
## 468                     semiconductors
##
##
## Community 5 :
##                     company_id community                               industry
## 11                         aes         5                              utilities
## 16                air-products         5                              chemicals
## 19                   albemarle         5                              chemicals
## 27              alliant-energy         5                              utilities
## 32                      ameren         5                              utilities
## 34     american-electric-power         5                              utilities
## 53                atmos-energy         5                              utilities
## 89                    celanese         5                              chemicals
## 92           centerpoint-energy         5                              utilities
## 95               cf-industries         5                              chemicals
## 114                 con-edison         5                              utilities
## 118            consumers-energy         5                              utilities
## 140                   dominion         5                              utilities
## 142               dow-chemical         5                              chemicals
## 144                 dte-energy         5                              utilities
## 145    duke-energy-corporation         5                              utilities
## 147   eastman-chemical-company         5                              chemicals
## 151        edison-international         5                              utilities
## 156                    entergy         5                              utilities
## 164            eversourceenergy         5                              utilities
## 165                     exelon         5                              utilities
## 169                 exxonmobil         5                           oil & energy
## 177            firstenergy-corp         5                              utilities
## 182                  flowserve         5 mechanical or industrial engineering
## 183                      fluor         5                           construction
## 184             fmc-corporation         5                              chemicals
## 190         freeport-mcmoran-inc         5                        mining & metals
## 227                        ihs         5                   information services
```

```
## 244                   jacobs         5                          construction
## 271          lyondell-basell         5                             chemicals
## 276 marathon-petroleum-company         5                          oil & energy
## 279  martin-marietta-materials         5                       mining & metals
## 302              mosaiccompany         5                       mining & metals
## 312 newmont-mining-corporation         5                       mining & metals
## 314   nextera-energy-resources         5              renewables & environment
## 317                   nisource         5                             utilities
## 324                 nrg-energy         5                          oil & energy
## 325          nucor-corporation         5                       mining & metals
## 346            ppl-corporation         5                             utilities
## 353                       pseg         5                             utilities
## 385           southern-company         5                             utilities
## 413            the-linde-group         5                             chemicals
## 437  valero-energy-corporation         5                          oil & energy
## 448   vulcan-materials-company         5                       mining & metals
## 454           wec-energy-group         5                             utilities
## 466                xcel-energy         5                             utilities
##
##
## Community 7 :
##                              company_id community
## 14                                  aig         7
## 26                        alliance-data         7
## 28                             allstate         7
## 38   ameriprise-financial-services-inc         7
## 45                               anthem         7
## 46                                  aon         7
## 50          arthur-j--gallagher-and-co         7
## 51                             assurant         7
## 60                      bank-of-america         7
## 62                                 bb&t         7
## 64                   berkshire-hathaway         7
## 67                            blackrock         7
## 68                           bny-mellon         7
## 75      broadridge-financial-solutions         7
## 81                          capital-one         7
## 86                                 cboe         7
## 91                  centene-corporation         7
## 96                       charles-schwab         7
## 100                               chubb         7
## 102                               cigna         7
## 106                                citi         7
## 107                       citizens-bank         7
## 109                           cme-group         7
## 113                       comerica-bank         7
## 135        discover-financial-services         7
## 162                              etrade         7
## 163                  everest-reinsurance         7
## 175                    fifth-third-bank         7
## 176                  first-republic-bank         7
## 178                                 fis         7
## 179                              fiserv         7
## 189     franklin-templeton-investments         7
```

```
## 200                       global-payments         7
## 201                         goldman-sachs         7
## 209                                   hca         7
## 222                                humana         7
## 223              huntington-national-bank         7
## 234          intercontinentalexchange-inc-         7
## 238                          invesco-ltd         7
## 246                            jefferies         7
## 250                       jpmorgan-chase         7
## 254                              keybank         7
## 267               lincoln-financial-group         7
## 272                             m&t-bank         7
## 278     marsh-&-mclennan-companies-inc-         7
## 289                              metlife         7
## 300                   moodys-corporation         7
## 301                       morgan-stanley         7
## 304                             msci-inc         7
## 321                       northern-trust         7
## 337               people%27s-united-bank         7
## 344                             pnc-bank         7
## 348            principal-financial-group         7
## 350                progressive-insurance         7
## 352                 prudential-financial         7
## 360          raymond-james-financial-inc-         7
## 366       regions-financial-corporation         7
## 390                         state-street         7
## 392                        suntrust-bank         7
## 395                  synchrony-financial         7
## 397                       t--rowe-price         7
## 404 the-cincinnati-insurance-companies         7
## 408                        the-hartford         7
## 418                torchmark-corporation         7
## 420                           travelers         7
## 426                                 uhs         7
## 433                   unitedhealth-group         7
## 434                                unum         7
## 436                             us-bank         7
## 441                     verisk-analytics         7
## 455                            wellcare         7
## 456                          wellsfargo         7
## 464                 willis-towers-watson         7
## 472                 zions-bancorporation         7
##                                industry
## 14                            insurance
## 26          marketing and advertising
## 28                            insurance
## 38                   financial services
## 45                            insurance
## 46                   financial services
## 50                            insurance
## 51                            insurance
## 60                              banking
## 62                   financial services
## 64                            insurance
```

```
## 67                    financial services
## 68                    financial services
## 75                    financial services
## 81                    financial services
## 86                    financial services
## 91                hospital & health care
## 96                    financial services
## 100                            insurance
## 102        health, wellness and fitness
## 106                   financial services
## 107                              banking
## 109                   financial services
## 113                              banking
## 135                   financial services
## 162                   financial services
## 163                            insurance
## 175                   financial services
## 176                              banking
## 178 information technology and services
## 179 information technology and services
## 189                   financial services
## 200                   financial services
## 201                   financial services
## 209               hospital & health care
## 222                            insurance
## 223                              banking
## 234                   financial services
## 238                investment management
## 246                   investment banking
## 250                   financial services
## 254                              banking
## 267                   financial services
## 272                   financial services
## 278                   financial services
## 289                            insurance
## 300                   financial services
## 301                   financial services
## 304                   financial services
## 321                   financial services
## 337                   financial services
## 344                   financial services
## 348                   financial services
## 350                            insurance
## 352                   financial services
## 360                   financial services
## 366                              banking
## 390                   financial services
## 392                   financial services
## 395                   financial services
## 397                investment management
## 404                            insurance
## 408                   financial services
## 418                   financial services
## 420                            insurance
```

```
## 426             hospital & health care
## 433             hospital & health care
## 434                          insurance
## 436                            banking
## 441               information services
## 455                          insurance
## 456                 financial services
## 464                 financial services
## 472                            banking
##
##
## Community 9 :
##               company_id community    industry
## 15                 aimco         9 real estate
## 56  avalonbay-communities         9 real estate
## 160    equity-residential         9 real estate
## 161  essex-property-trust         9 real estate
## 425                   udr         9 real estate
##
##
## Community 8 :
##                              company_id community
## 21  alexandria-real-estate-equities-inc-         8
## 71                     boston-properties         8
## 87                                  cbre         8
## 134                         digitalrealty         8
## 146             duke-realty-corporation         8
## 173      federal-realty-investment-trust         8
## 210                                   hcp         8
## 257            kimco-realty-corporation         8
## 273                              macerich         8
## 295    mid-america-apartment-communities         8
## 351                              prologis         8
## 364                       regency-centers         8
## 381                 simon-property-group         8
## 383                              sl-green         8
## 439                           ventas-inc.         8
## 447                 vornado-realty-trust         8
## 457                             welltower         8
##                              industry
## 21                        real estate
## 71                        real estate
## 87                        real estate
## 134 information technology and services
## 146                       real estate
## 173                       real estate
## 210                       real estate
## 257                       real estate
## 273                       real estate
## 295                       real estate
## 351                       real estate
## 364                       real estate
## 381                       real estate
## 383                       real estate
```

```
## 439                         real estate
## 447                         real estate
## 457                         real estate
##
##
## Community 3 :
##                             company_id community     industry
## 42     anadarko-petroleum-corporation         3 oil & energy
## 47                  apache-corporation         3 oil & energy
## 58                        baker-hughes         3 oil & energy
## 78                     cabot-oil-&-gas         3 oil & energy
## 98                             chevron         3 oil & energy
## 103                     cimarex-energy         3 oil & energy
## 115                   concho-resources         3 oil & energy
## 116                     conocophillips         3 oil & energy
## 132                       devon-energy         3 oil & energy
## 133       diamondback-energy-services         3 oil & energy
## 157                      eog-resources         3 oil & energy
## 204                        halliburton         3 oil & energy
## 211                  helmerich-&-payne         3 oil & energy
## 213                    hess-corporation         3 oil & energy
## 216         hollyfrontier-corporation         3 oil & energy
## 258                      kinder-morgan         3 oil & energy
## 275           marathon-oil-corporation         3 oil & energy
## 307             national-oilwell-varco         3 oil & energy
## 318                       noble-energy         3 oil & energy
## 328                              oneok         3 oil & energy
## 330                                oxy         3 oil & energy
## 342                        phillips66co         3 oil & energy
## 343 pioneer-natural-resources-company         3 oil & energy
## 376                       schlumberger         3 oil & energy
## 463                   williams-company         3 oil & energy
##
##
## Community 10 :
##                 company_id community                 industry
## 84  carnival-cruise-lines        10 leisure, travel & tourism
## 323 norwegian-cruise-line        10 leisure, travel & tourism
## 373       royal-caribbean        10 leisure, travel & tourism
```

Community Detection Insights

Based on the results, each detected community largely consists of firms from the same or related industries. This suggests that companies tend to form communities based on industry affinity.

Key Patterns and Implications

1. **Industry Clustering**
   Firms within the same or similar industries tend to be more interconnected through talent flows and business relationships.
2. **Strategic Alignment**
   Some communities may reflect strategic partnerships, supply chains, or a shared market focus.
3. **Knowledge and Talent Exchange**

Intra-industry communities can facilitate the flow of expertise and innovation, which are critical for competitiveness and growth.

These patterns provide insight into how industry structure influences firm interactions and highlight potential collaboration or talent movement within sectors.

Understanding Assortative Mixing

Assortative mixing describes the tendency of nodes in a network to connect with others that share similar characteristics.

In this context, assortative mixing by **industry** means that firms are more likely to connect (e.g., through talent flow or business relationships) with other firms in the **same industry**, rather than with firms from different sectors.

Compute Assortativity by Industry

```
industries <- df_company$industry[match(V(graph_df_edges)$name, df_company$company_id)]
industries <- factor(industries)

assortativity_coefficient <- assortativity(graph_df_edges, types1 = industries, directed = FALSE)
print(assortativity_coefficient)
```

```
## [1] 0.02631082
```

This concludes the end-to-end analysis of a talent flow network using `igraph` in R. The project identifies key players in employee movement, explores community and industry-level patterns, and investigates structural dynamics such as assortativity and influence.