

*University of British Columbia Okanagan*  
*COSC 421 /COSC 521 Network Science*  
*Assignment 4*

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You are required to use the [igraph package](#) in R for this assignment.

For this assignment, upload only your R file that includes your code and answers to the questions below. For questions that require explanations, use comments (#) for the explanation. In your R file clearly indicate the question numbers so that it is clear to the TA what code or explanation corresponds to what question. Feel free to ask the TA (during the helpdesk session) or the instructor (during office hours) for help with the assignment. You are required to **work alone** on this assignment.

This assignment is on centrality measures and subgroups in the September 11, 2001 terrorist network. In his paper, "Uncloaking Terrorist Networks" Valdis Krebs used social network analysis to map the terrorist network that attacked on 9/11.  
(<https://firstmonday.org/ojs/index.php/fm/article/view/941/863>)

Within one week of the attack on Sept 11, 2001, information from the investigation started to become public. It was soon known that there were 19 hijackers, which planes they were on, and which nation's passports they had used to get into America. Valdis Krebs created the network iteratively as data became available through the major news sources.

The network relation (edge) indicates some kind of “connection” between two members prior to the final action on Sept 11, 2001. This is based on prior contacts in family, neighborhood, school, military, club or organization; public and court records, phone calls, electronic mail, chat rooms, instant messages, Web site visits, travel records, human intelligence observation of meetings and attendance at common events; monetary connections based on bank account and money transfer records, pattern and location of credit card use, intelligence observation of visits to alternate banking resources such as Hawala.

Data: The data on 61 suspects is stored as an adjacency matrix in the file adj911.csv. The file vertex911.csv **contains the names, network strength, and ties** of 61 men accused (some wrongly) of being associated in various roles, including 19 directly involved in hijacking planes. The first 19 in the list are the 19 directly involved in hijacking planes and their ties show the flight that they hijacked.

**Network strength** is one of these two:

- 1 = Trusted Prior contacts
- 2 = Other associates

**The Ties** show the flight each man was on and is one of the following:

- 1 = AA #11 WTC North
- 2 = AA #77 Pentagon

3 = UA #93 Pennsylvania  
4 = UA #175 WTC South  
5 = Other Associates

Further, the following four men were pilots of the hijacked planes:

1. Hani Hanjour
2. Mohamed Atta
3. Marwan Al-Shehhi
4. Ziad Jarrah

Load the data files to R by

```
> nodes <- read.csv("vertex911.csv", header = T)
> adj <- read.csv("adj911.csv", header=T)
> head(adj) # to see how the data look like
```

```
adj <- as.matrix(adj) # convert to R matrix object
```

Create a graph object in R by

```
g <- graph_from_adjacency_matrix(adj, mode = "undirected")
```

**Question 1 [2 marks].**

Plot the undirected network. Since the vertices have long names, you may omit the vertex labels for clarity by option **vertex.label=NA**. Assign a special color (red) to the hijackers and blue to all others. Describe some main features of the network such as disconnected components, position of the hijackers in the network, and how closely hijackers were interconnected.

**Question 2 [2 marks].** Use the eigenvalue centrality measure to list the top five central members of the network by their name. Which hijackers, if any, are on this list?

**Question 3 [3 marks].** Compute the closeness centrality and betweenness centrality scores for the vertices and identify the top five men in the network by each of these measures. Which of the hijackers, if any, are on these two lists?

**Question 4 [5 marks].** Find the counts of cliques of different sizes by:

```
> table(sapply(cliques(g), length)) or
> clique_size_counts(g)
```

- (a) What is the largest size (given by length) of cliques? How many cliques are of the largest size? List all the cliques of the largest size by:

```
cliques(g) [sapply(cliques(g), length) == size]
```

- (b) Which of the hijackers were part of these cliques? Which of the pilots were and were not part of these cliques?

**Question 5 [6 marks].** Create a sub-graph of 19 hijackers only by

```
g2 <- graph_from_adjacency_matrix(adj[1:19,1:19], mode =  
"undirected")
```

Assign colours to nodes by the flight that they hijacked by

```
V(g2)$color <- nodes[1:19,3]
```

- (a) Draw a plot of the graph using different vertex colors for hijackers of the four flights. Did all the hijackers on a given flight know the pilot hijacker of that flight?
- (b) List the cliques of the largest size in this subgraph. Did any pilot belong to these cliques? Did all the four pilots know one another?

**Question 6 [2 marks].**

What suspect has the highest influence in the network and why?