Homework 4

SIMULATION OF COMPLEX SYSTEMS

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Exercise 1

The Erdõs-Rényi random graph

- Visualisation of the network (a graph plot)
- Degree distribution plot

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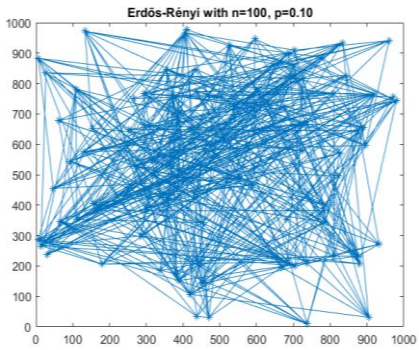
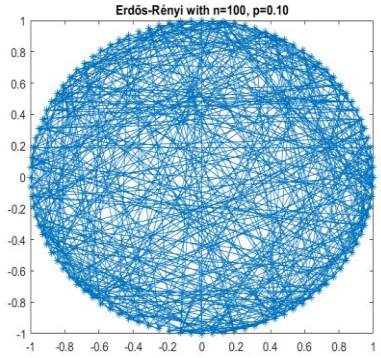
Network

RANDOM NODE LOCATION



NODES POSITIONED IN A CIRCLE



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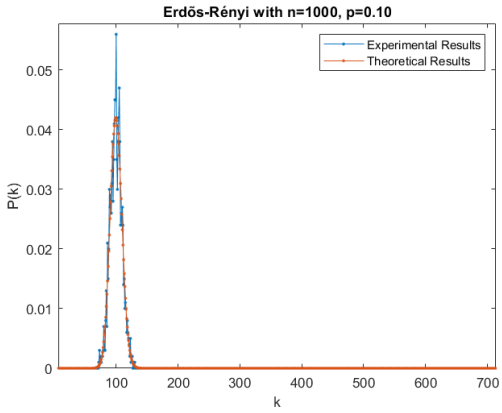
Degree Distribution



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Exercise 2

The Watts-Strogatz small world model

- Network before the shortcuts
- Network after the shortcuts

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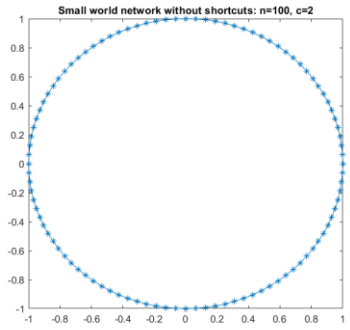
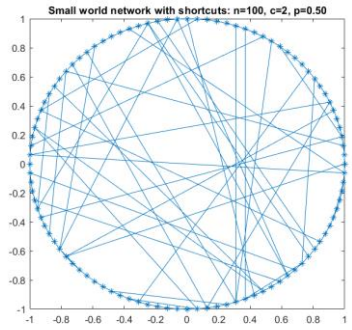
N=100

WITHOUT SHORTCUTS



WITH SHORTCUTS



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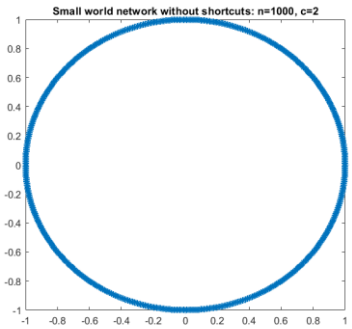
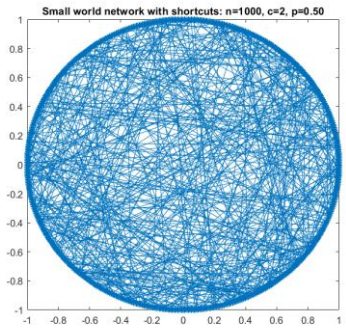
N=1000

WITHOUT SHORTCUTS



WITH SHORTCUTS



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Exercise 3

The Albért-Barabási preferential growth model

- Visualisation of the network
- Power law plot

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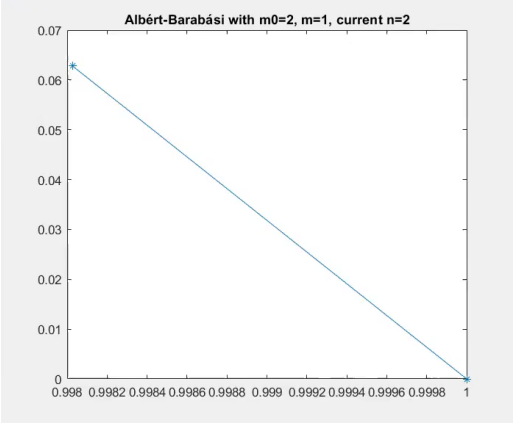
Network



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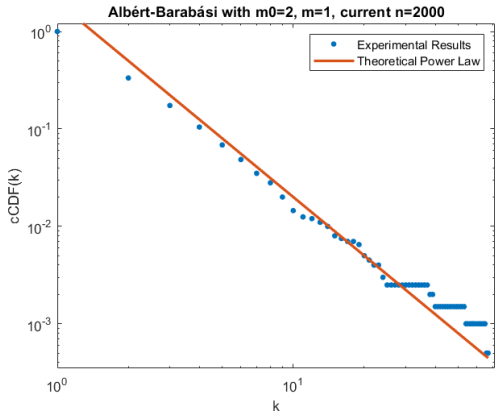
Power-law Plot



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Exercise 4

- A graph plot of the example network
- The calculated clustering coefficient for the example graph
- Code snippet showing the algorithm

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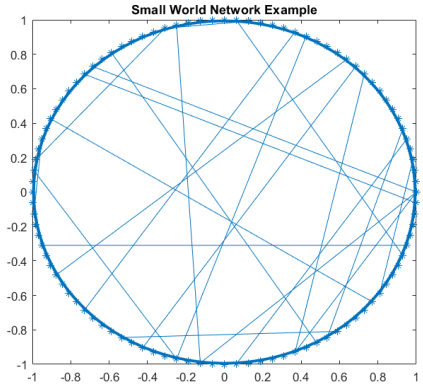
Network



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Code and Results

```
n_tri = 0;
for i=1:n
    for j=1:n
        for k=1:n
            n_tri = n_tri + (adj(i,j)*adj(k,i)*adj(j,k));
        end
    end
end
n_all_tri=0;
for i=1:n
    sum = 0;
    for j=1:n
        sum = sum + adj(i,j);
    end
    n_all_tri = n_all_tri + sum*(sum-1);
end

format long g;
disp(n_tri/n_all_tri);
```

Clustering Coefficient = 0.611280

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Exercise 5

- The calculated average path length of the example graph
- Code snippet showing the algorithm

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Code and Results

```
%Distance
dist = adj;
for i=1:n
        for j=1:n
            if dist(i,j) == 0 && i~=j
                dist(i,j) = Inf;
            end
        end
end

for k=1:n
    for i=1:n
        for j=1:n
            dist(i,j) = min(dist(i,j),dist(i,k)+dist(k,j));
        end
    end
end

len=0;
for i=1:n
    for j=1:n
            len = len + dist(i,j);
    end
end

disp(len/(n*(n-1)));
```

Average Path Length = 2.93232

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Exercise 6

- Calculated results and identification of each network, explained in terms of the results
  - Social network of email exchanges at a Spanish university
  - The Western States power grid
  - The (largest cluster of the) protein interaction network in yeast

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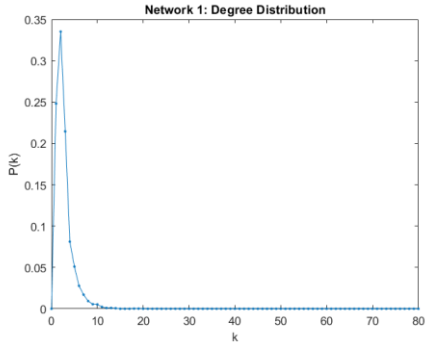
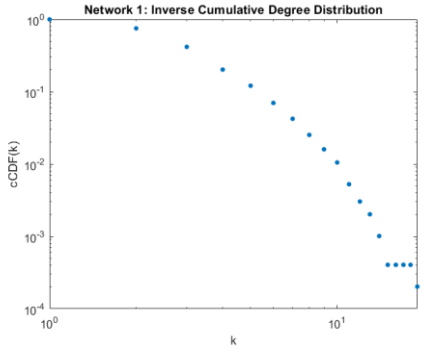
Network 1

DEGREE DISTRIBUTION



INVERSE CUMULATIVE DEGREE DISTRIBUTION



Clustering Coefficient = 0.103153; Average Path Length = 18.989185; Diameter = 46

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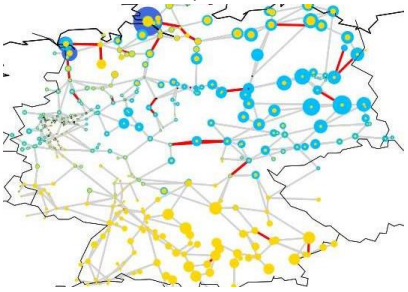
Network 1 = Power Grid

Power grids can be seen as radial networks.

The peripheral nodes have a small number of edges (and there are no shortcuts from one side to the other)

Therefore, the average path length and diameter are high for these networks, as we verified for this case.



Example of a power grid network

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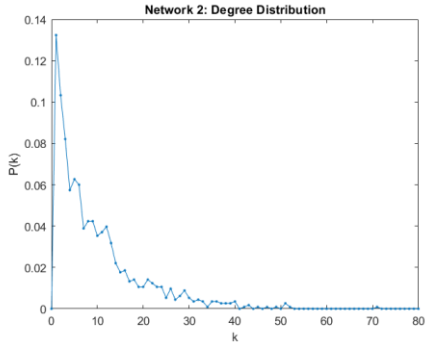
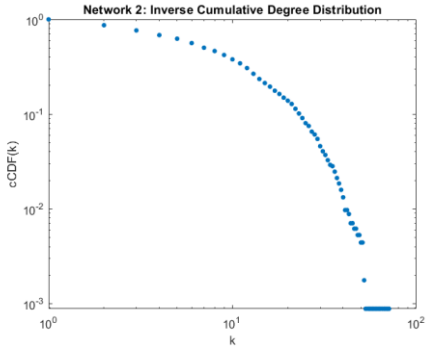
Network 2

DEGREE DISTRIBUTION



INVERSE CUMULATIVE DEGREE DISTRIBUTION



Clustering Coefficient = 0.166269; Average Path Length = 3.606033; Diameter = 8

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Network 2 = Social Network

In social networks, nodes tend to create tightly knit groups characterised by a relatively high density of ties

As expected, this network has the highest clustering coefficient of the three networks

It also has a low average path length as well as a low diameter.

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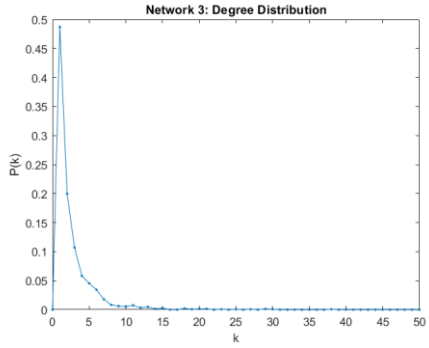
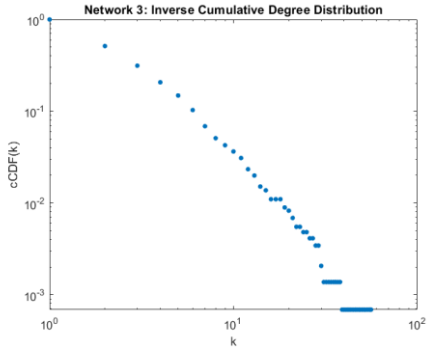
Network 3

DEGREE DISTRIBUTION



INVERSE CUMULATIVE DEGREE DISTRIBUTION



Clustering Coefficient = 0.0793696; Average Path Length = 6.812387; Diameter = 19

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Network 3 = Protein-Protein Interaction

It is a scale free network.

Scale-free networks can be built following the **preferential attachment model.**

The inverse cumulative degree distribution clearly shows that the degree distribution fits a power law

The average path length is also relatively small as expected

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