

Homework Assignment 2: Network Flows

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Circular Layout

As the name suggest this layout positions nodes in a circle [13]. According to [14] although this algorithm can appear trivial, it is widely used to visualize complexes and pathways. The algorithm attempts to minimize the number of overlapping nodes and edges, this way interactions among nodes are easier to understand and locate. It allows to highlight the node or nodes with the highest degree, moreover it evidences potentially interesting sub-networks as inner circles in the network [1].

```
1 import networkx as nx
2 import matplotlib.pyplot as plt
3
4 G=nx.Graph()
5 G.add_nodes_from(['A','B','C','D','E'])
6
7 G.add_edges_from([('A','B'),('B','C'),('C','D'),('D','E'),('E','A')])
8
9 nx.draw(G,pos=nx.circular_layout(G),with_labels=True) #Draw the Graph named G with the
10 circular layout
11 plt.savefig("Graph02.eps", format="EPS")
12 plt.show()
```

graph02ucg.py

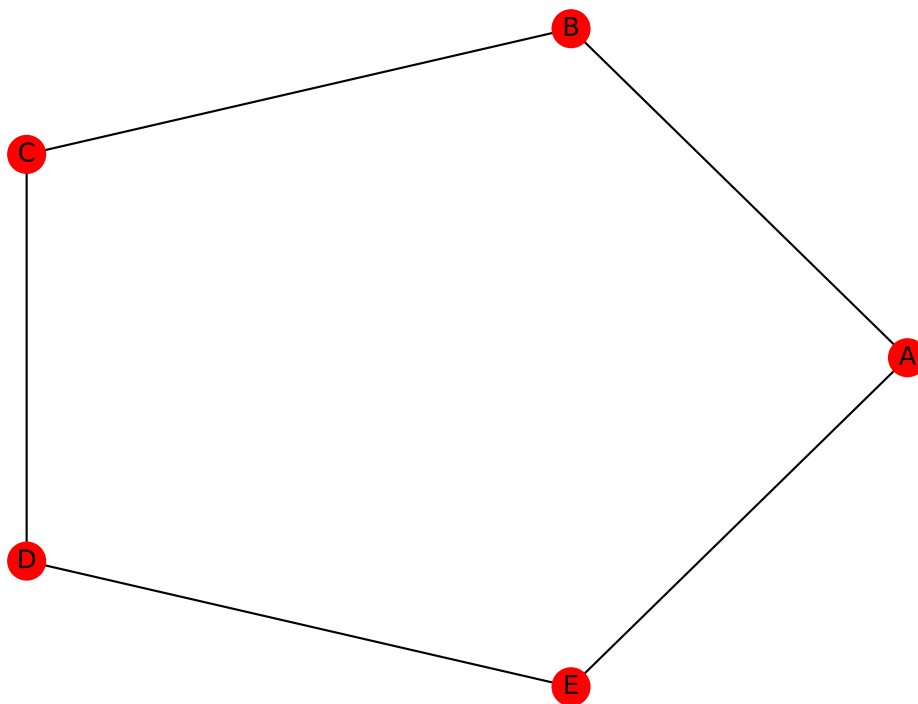


Figure 1: Circular layout

Random Layout

This algorithm positions nodes by choosing coordinates uniformly at random on the interval $[0.0, 1.0)$ where the nodes are generated [13]. The advantage of this kind of layout lays in the very fast drawing on the network graph. However it carries the disadvantage of the difficulty in grasping the position of nodes [12].

```
1 import networkx as nx
2 import matplotlib.pyplot as plt
3
4 R=nx.DiGraph()
5 R.add_nodes_from(["D","1","2","3","4"])
6
7 R.add_edges_from([("D","1"),("1","2"),("2","D")])
8 R.add_edges_from([("D","3"),("3","4"),("4","D"),("D","D")])
9
10 color_map = []
11 for node in R:
12     if (node == "D"):
13         color_map.append('blue')
14     else:
15         color_map.append('red')
16
17 nx.draw(R, node_color=color_map, pos=nx.random_layout(R), with_labels=True)
18 plt.savefig("Graph06.eps", format="EPS")
19 plt.show()
```

graph06drg.py

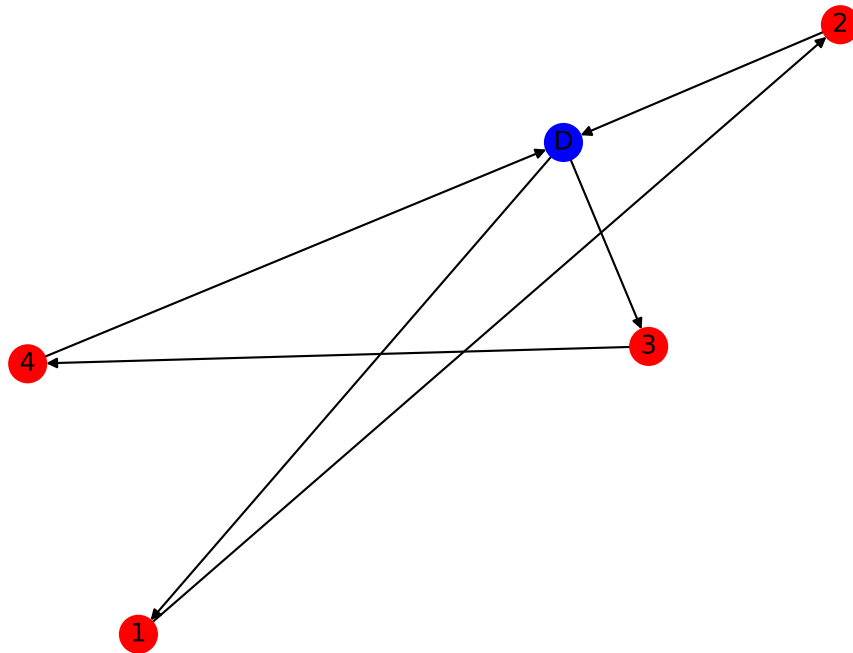


Figure 2: Random layout

Bipartite Layout

This layout positions nodes in two straight lines [13]. This particular class only allows the connection between two nodes in different sets [4]. Nodes from set X are only connected with nodes from set Y, not with other nodes from X, and vice versa [9].

```
1 import networkx as nx
2 import matplotlib.pyplot as plt
3
4 M=nx.MultiDiGraph()
5 M.add_nodes_from(["Coahuila", "Veracruz"], bipartite=0)
6 M.add_nodes_from(["Sonora", "Guanajuato", "Quintana_Roo"], bipartite=1)
7
8 M.add_edge("Sonora", "Coahuila", color='blue', weight=1)
9 M.add_edges_from([("Coahuila", "Sonora"), ("Coahuila", "Guanajuato"), ("Guanajuato", "Veracruz"), ("
    Veracruz", "Quintana_Roo"), ("Quintana_Roo", "Coahuila")], color='black', weight=1)
10
11 edges = M.edges()
12
13 colors = []
14 weight = []
15
16 for (u,v,attrib_dict) in list(M.edges.data()):
17     colors.append(attrib_dict['color'])
18     weight.append(attrib_dict['weight'])
19
20 nx.draw(M, pos=nx.bipartite_layout(M, ["Coahuila", "Veracruz"]), edges=edges, edge_color=colors,
    width=weight, with_labels=True)
21 plt.savefig("Graph11.eps", format="EPS")
22 plt.show()
```

graph11dcm.py

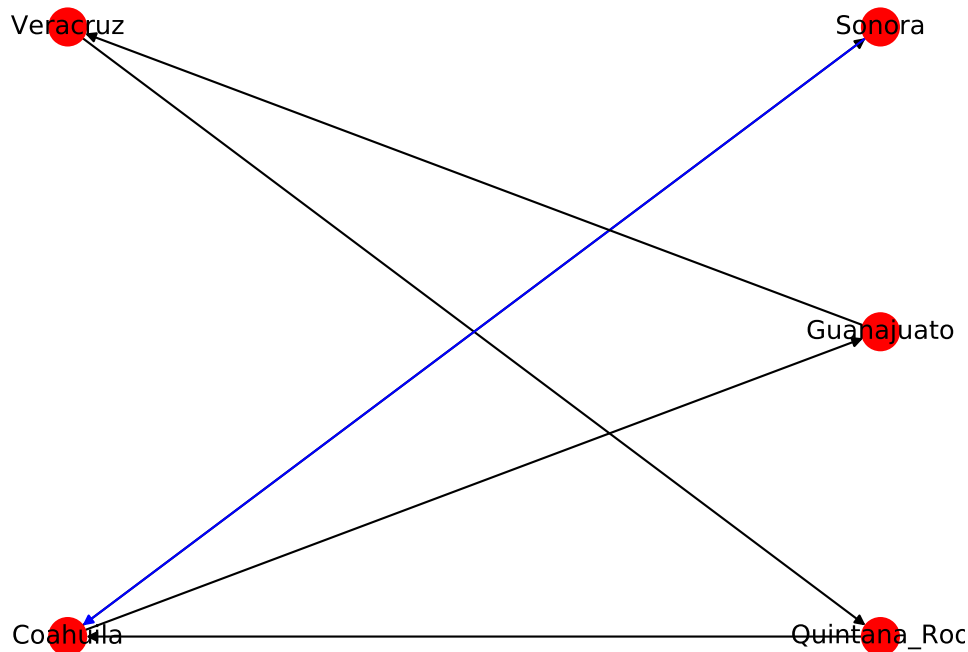


Figure 3: Bipartite layout

Kamada-Kawai Layout

Is an algorithm for drawing undirected graphs and weighted graphs and is based on the concept of theoretic distance between nodes [8]. In this algorithm the forces between the nodes can be determined by the lengths of shortest paths between each couple of nodes [13]. The classical Kamada-Kawai algorithm does not scale well when it is used in networks with large numbers of nodes [2].

This layout will be represented by an undirected reflexive graph and a directed acyclic multigraph.

Undirected reflexive graph

```
1 import networkx as nx
2 import matplotlib.pyplot as plt
3
4 H=nx.Graph()
5 H.add_nodes_from([0,1,2])
6 H.add_nodes_from([3,4])
7
8 H.add_edges_from([(0,1),(0,2),(1,2),(0,3),(0,4),(3,3)])
9
10 color_map = []
11 for node in H:
12     if (node == 3):
13         color_map.append('blue')
14     else:
15         color_map.append('red')
16
17 pos = nx.kamada_kawai_layout(H)
18
19 nx.draw(H, pos=pos, node_color=color_map, with_labels=True)
20 plt.savefig("Graph03.eps", format="EPS")
21 plt.show()
```

graph03urg.py

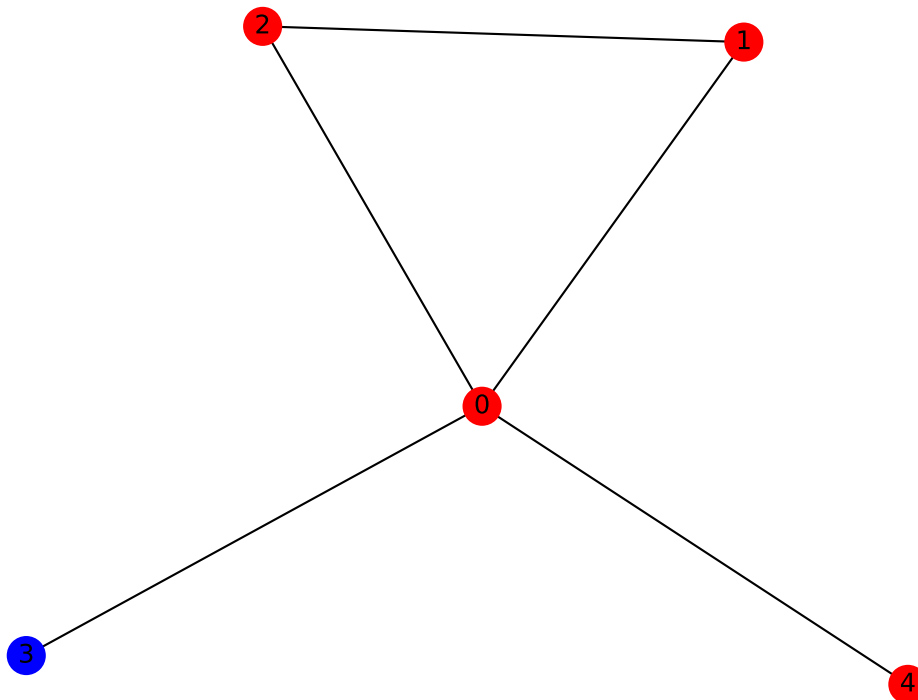


Figure 4: Kamada-Kawai layout for the undirected reflexive graph

Directed acyclic multigraph

```
1 import networkx as nx
2 import matplotlib.pyplot as plt
3
4 M=nx.MultiDiGraph()                                #Create an empty directed multigraph
5
6 M.add_nodes_from(["x1","x2","x3","x4","x5"])
7
8 M.add_edge("x1","x2",color='green',weight=6)
9 M.add_edges_from([("x1","x2"),("x3","x2"),("x4","x3"),("x4","x2"),("x5","x2")],color='black',
10                  weight=1)
11
12 edges = M.edges()
13
14 colors = []
15 weight = []
16
17 for (u,v,attrib_dict) in list(M.edges.data()):
18     colors.append(attrib_dict['color'])
19     weight.append(attrib_dict['weight'])
20
21 pos=nx.kamada_kawai_layout(M)
22
23 nx.draw(M,pos=pos,edges=edges,edge_color=colors,width=weight,with_labels=True)
24 plt.savefig("Graph10.eps",format="EPS")
25 plt.show()
```

graph10dam.py

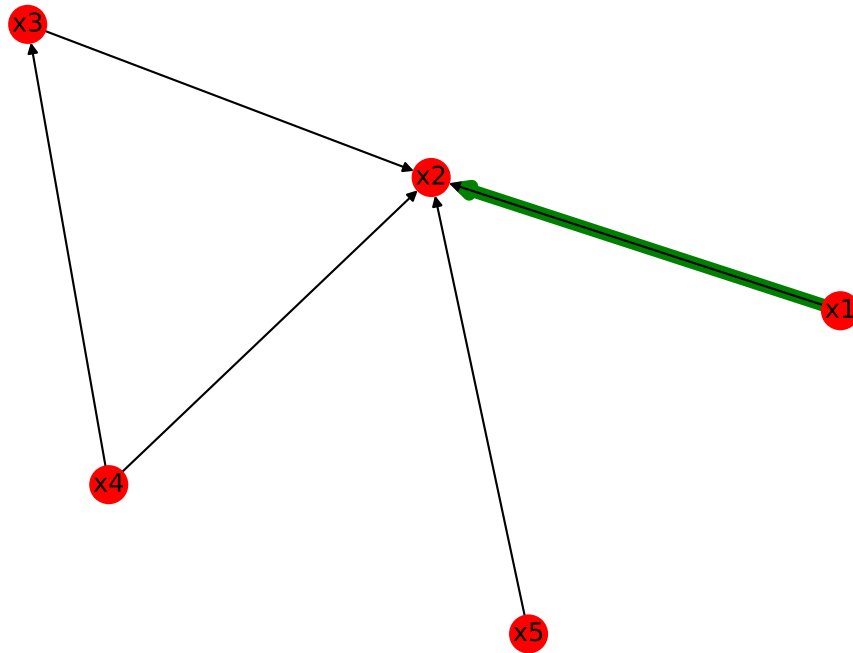


Figure 5: Kamada-Kawai layout for the directed acyclic multigraph

Shell Layout

This layout positions nodes in concentric circles [13]. It is also known as concentric layout in [3], where it is said that this arrangement in a series of concentric circles is based on the distance from the central node. Thus, nodes with direct connections are arranged in the first circle, then the nodes located at a distance of two nodes away from the center follows in this arrangement and so on, until the graph is completed. The main advantage of this layout is that viewers are able to see network structures easier and to navigate them noticing the closeness of relationships to a single node to each other.

This layout will be represented by a directed cyclic graph and a directed reflexive multigraph.

Directed cyclic graph

```
1 import networkx as nx
2 import matplotlib.pyplot as plt
3
4 G = nx.DiGraph()
5 G.add_node('DEPOT')
6 G.add_nodes_from(['Job1', 'Job2', 'Job3', 'Job6'])
7 G.add_nodes_from(['Job4', 'Job5', 'Job7'])
8 G.add_nodes_from(['Job8', 'Job9'])
9
10 G.add_path(['DEPOT', 'Job1', 'Job2', 'Job3', 'Job6', 'DEPOT']) #Construct a path from the nodes in
    that order
11 G.add_path(['DEPOT', 'Job4', 'Job5', 'Job7', 'DEPOT'])
12 G.add_path(['DEPOT', 'Job8', 'Job9', 'DEPOT'])
13
14 pos=nx.shell_layout(G)
15 nx.draw(G, pos=pos, with_labels=True)
16 plt.savefig("Graph05.eps", format="EPS")
17 plt.show()
```

graph05dcd.py

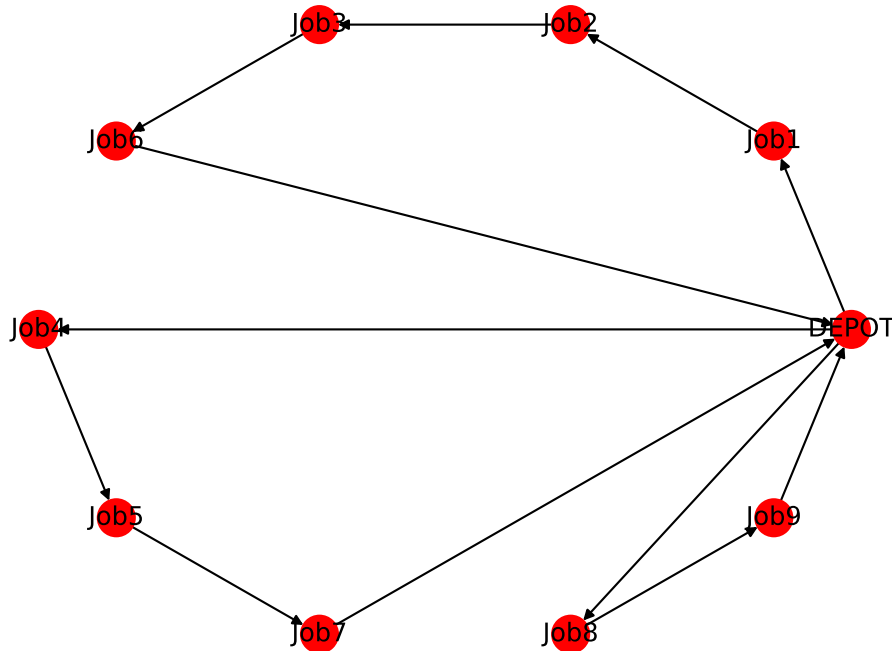


Figure 6: Shell layout for the directed cyclic graph

Directed reflexive multigraph

```
1 import networkx as nx
2 import matplotlib.pyplot as plt
3
4 M=nx.MultiDiGraph()
5
6 M.add_nodes_from(["Depot", "Warehouse1", "Warehouse2", "Warehouse3", "Warehouse4"])
7
8 M.add_edges_from([("Depot", "Warehouse1"), ("Depot", "Warehouse1"), ("Depot", "Warehouse2"), ("Depot",
9     "Warehouse3"), ("Depot", "Warehouse4"), ("Depot", "Depot")])
10
11 color_map = []
12 for node in M:
13     if (node == 3):
14         color_map.append('blue')
15     else:
16         color_map.append('red')
17
18 pos=nx.shell_layout(M)
19 nx.draw(M, pos=pos, node_color=color_map, with_labels=True)
20 plt.savefig("Graph12.eps", format="EPS")
21 plt.show()
```

graph12drm.py

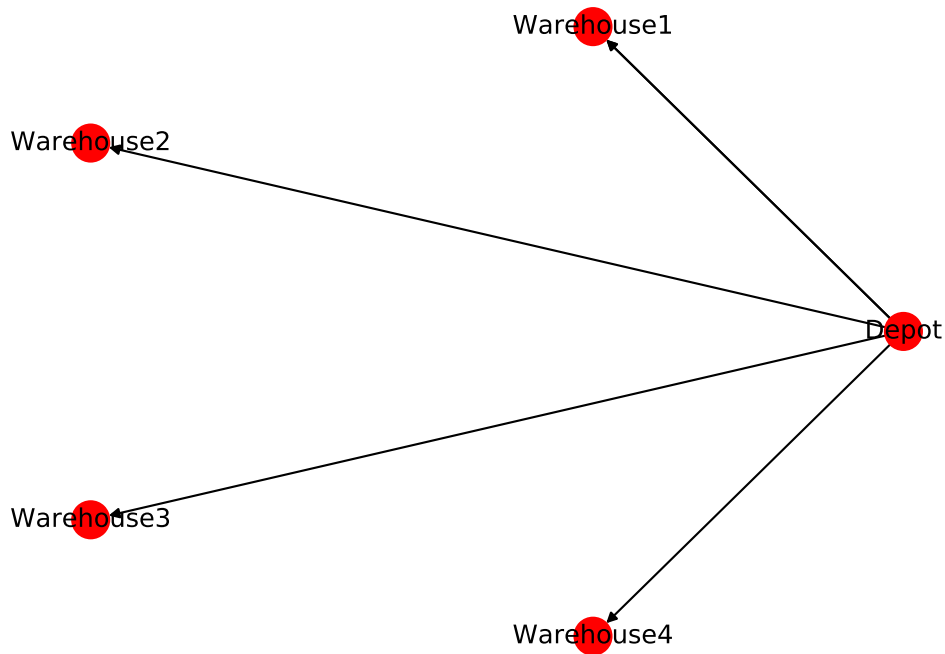


Figure 7: Shell layout for the directed cyclic graph

Fruchterman-Reingold Layout

This algorithm attempts to distribute vertices evenly, make edge lengths uniform, and reflect symmetry [5]. Is best for fewer than thirty nodes and does not require parameters to be optimised [6]. This layout will be represented by an undirected acyclic multigraph and a directed acyclic graph.

Undirected acyclic multigraph

```
1 import networkx as nx
2 import matplotlib.pyplot as plt
3
4 M = nx.MultiGraph()                                #Create an empty Multigraph
5
6 M.add_nodes_from(['x','y','z','v','w'])
7
8 M.add_edge('x','y',color='blue',weight=6)
9 M.add_edges_from([('x','y'),('x','y'),('y','z'),('z','v'),('v','w')],color='black',weight=1)
10
11 edges = M.edges()
12
13 colors = []
14 weight = []
15
16 for (u,v,attrib_dict) in list(M.edges.data()):
17     colors.append(attrib_dict['color'])
18     weight.append(attrib_dict['weight'])
19
20 pos = nx.fruchterman_reingold_layout(M,k=0.15,iterations=20)
21
22 nx.draw(M,pos=pos,edges=edges,edge_color=colors,width=weight,with_labels=True)
23 plt.savefig("Graph07.eps",format="EPS")
24 plt.show()
```

graph07uam.py

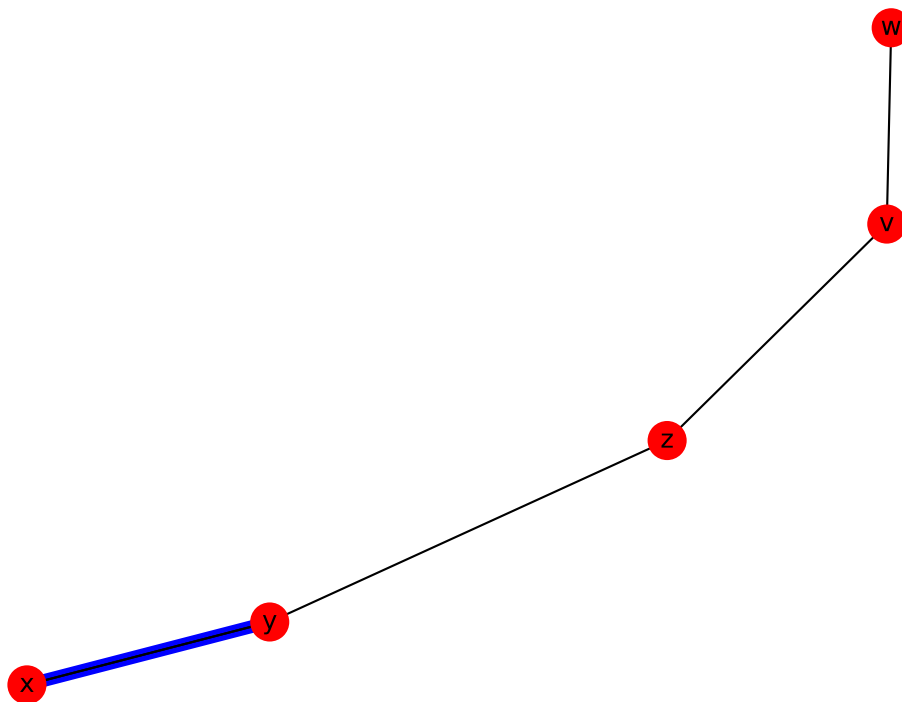


Figure 8: Fruchterman-Reingold layout for the undirected acyclic multigraph

Directed acyclic graph

```
1 import networkx as nx
2 import matplotlib.pyplot as plt
3
4 G=nx.DiGraph()                                #Create an empty directed graph
5 G.add_node("X")
6 G.add_nodes_from(["R1","R2","R3","R4"])
7
8 G.add_edges_from([("X","R1"),("X","R2"),("X","R3"),("X","R4")])
9
10 pos=nx.fruchterman_reingold_layout(G,k=0.2,iterations=30)
11
12 nx.draw(G,pos=pos,node_color='skyblue',with_labels=True)
13 plt.savefig("Graph04.eps",format="EPS")
14 plt.show()
```

graph04dag.py

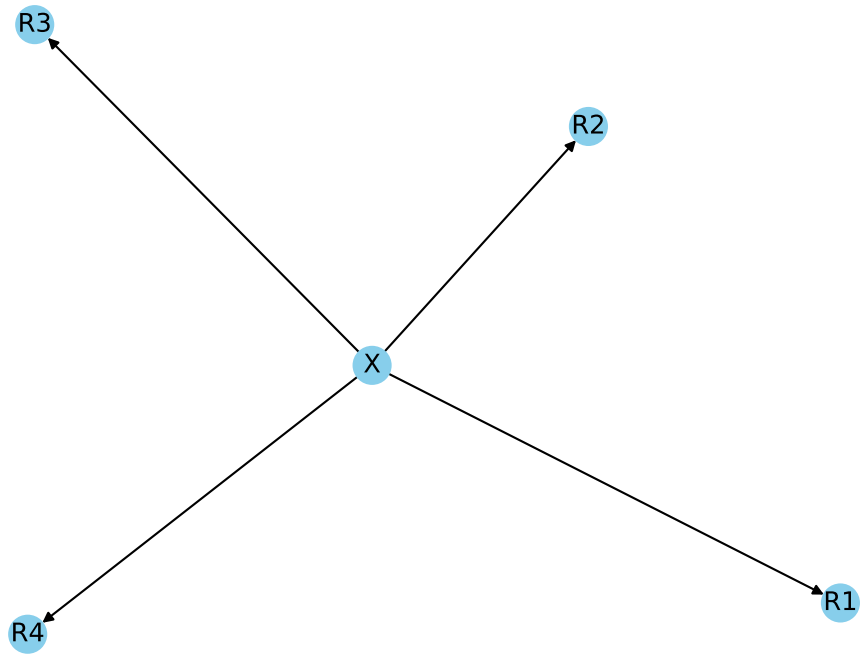


Figure 9: Fruchterman-Reingold layout for the directed acyclic graph

Spring Layout

This layout positions nodes using the algorithm of Fruchterman-Reingold [13]. The algorithm first places the vertices in some initial layout and then it moves the rings in which the system reach a minimal energy due to the spring forces. With this layout we should obtain a display as much symmetry as possible [10].

```
1 import networkx as nx
2 import matplotlib.pyplot as plt
3
4 M=nx.MultiGraph()
5
6 M.add_nodes_from([1,2,3,4,5])
7
8 M.add_edge(2,1, color='blue',weight=6)
9 M.add_edges_from([(1,2),(1,3),(3,4),(4,5),(5,1)],color='black', weight=1)
10
11 edges = M.edges()
12
13 colors = []
14 weight = []
15
16 for (u,v,attrib_dict) in list(M.edges.data()):
17     colors.append(attrib_dict['color'])
18     weight.append(attrib_dict['weight'])
19
20 pos = nx.spring_layout(M, scale=3)
21
22 nx.draw(M,pos,edges=edges,edge_color=colors,width=weight,with_labels=True, font_size=8,
23         font_family='sans-serif')
24 plt.savefig("Graph08.eps", format="EPS")
25 plt.show()
```

graph08ucm.py

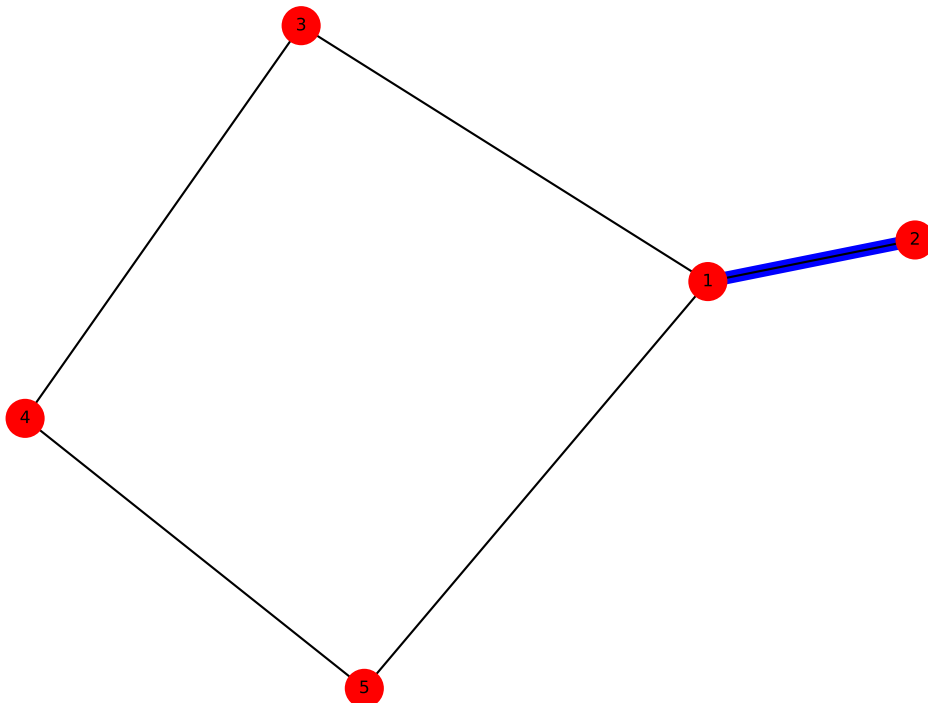


Figure 10: Spring layout

Spectral Layout

This approach has the advantage of computing optimal layouts (according to some requirements) and rapid computation time. It provides an exact solution to the layout problem, whereas other formulations end in an NP-hard problem with approximated solutions [11]. To construct the layout it uses eigenvectors of the adjacency matrix of the graph and of the Laplacian spectrum associated with the graph [11]. While we use this layout in Python using NetworkX, positioning the nodes, directed graphs will be considered as undirected graphs [13].

```
1 import networkx as nx
2 import matplotlib.pyplot as plt
3
4 M=nx.MultiGraph()
5 M.add_nodes_from(["A","B","C","D","E"])
6
7 M.add_edges_from([("A","B"),("A","C")],color='blue', weight=8)
8 M.add_edges_from([("A","A"),("A","B"),("A","C"),("B","C"),("B","D"),("C","E"),("D","E")],
9                 color='black', weight=2)
10
11 edges = M.edges()
12 colors = []
13 weight = []
14
15 for (u,v,attrib_dict) in list(M.edges.data()):
16     colors.append(attrib_dict['color'])
17     weight.append(attrib_dict['weight'])
18
19 g=nx.shell_layout(M)
20 nx.draw(M,edges=edges,pos=g,edge_color=colors,width=weight,with_labels=True)
21 #plt.savefig("Graph09.eps",format="EPS")
22 plt.show()
```

graph09urm.py

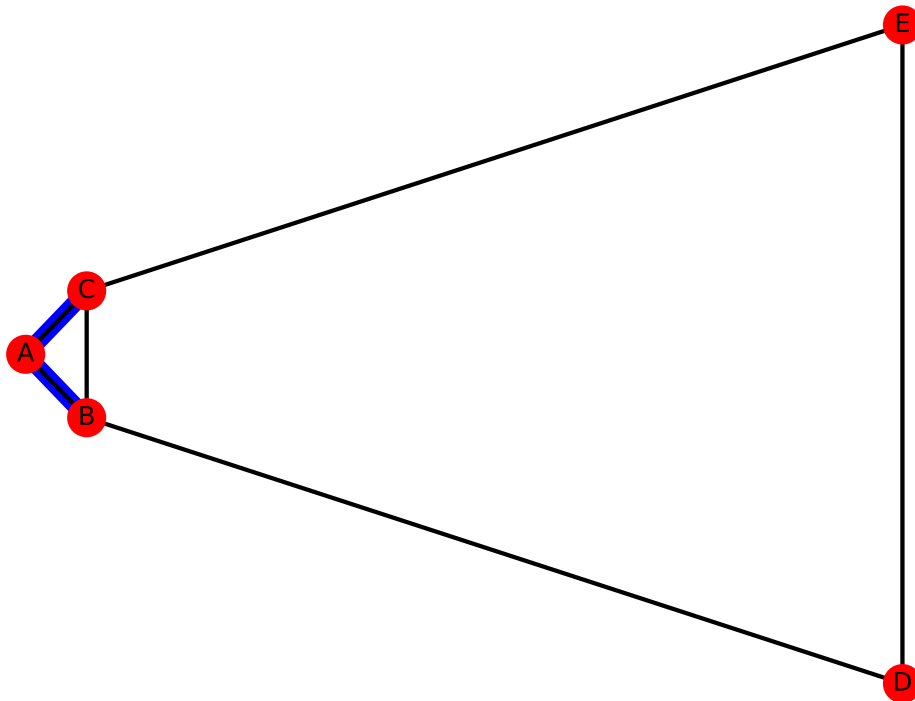


Figure 11: Spectral layout

Force Atlas 2 Layout

Force Atlas 2 is a very fast layout algorithm for force-directed graphs. It's used to spatialize a weighted undirected graph in 2D (Edge weight defines the strength of the connection). The implementation is based on [7]. It's really quick compared to the fruchterman reingold algorithm (spring layout) of networkx and scales well to high number of nodes.

```
1 import networkx as nx
2 from fa2 import ForceAtlas2
3 import matplotlib.pyplot as plt
4
5 G = nx.Graph()                                #Create an empty graph
6
7 G.add_node('Libro')                           #Add a simple node
8 G.add_nodes_from(['C1', 'C2', 'C3'])         #Add a list of nodes
9 G.add_nodes_from(['s1.1', 's1.2', 's2.1', 's2.2', 's2.3'])
10 G.add_nodes_from(['s2.1.1', 's2.1.2'])
11
12 G.add_edges_from([('Libro', 'C1'), ('Libro', 'C2'), ('Libro', 'C3')])
13 G.add_edges_from([('C1', 's1.1'), ('C1', 's1.2')])
14 G.add_edges_from([('C2', 's2.1'), ('C2', 's2.2'), ('C2', 's2.3')])
15 G.add_edges_from([('s2.1', 's2.1.1'), ('s2.1', 's2.1.2')])
16
17 #Consulted at: |https://github.com/bhargavchippada/forceatlas2
18 forceatlas2 = ForceAtlas2(
19     # Behavior alternatives
20     outboundAttractionDistribution=True, # Dissuade hubs
21     linLogMode=False,
22     adjustSizes=False,
23     edgeWeightInfluence=1.0,
24
25     # Performance
26     jitterTolerance=1.0,
27     barnesHutOptimize=True,
28     barnesHutTheta=1.2,
29     multiThreaded=False,
30
31     # Tuning
32     scalingRatio=2.0,
33     strongGravityMode=False,
34     gravity=1.0,
35
36     # Log
37     verbose=True)
38
39 positions = forceatlas2.forceatlas2_networkx_layout(G, pos=None, iterations=2000)
40
41 nx.draw_networkx_nodes(G, positions, node_size=100, with_labels=True, node_color="red", alpha=0.4)
42 nx.draw_networkx_edges(G, positions, edge_color="black", alpha=0.05)
43 plt.axis('off')
44 plt.savefig("Graph01.eps", format="EPS")
45 plt.show()
```

graph01uag.py

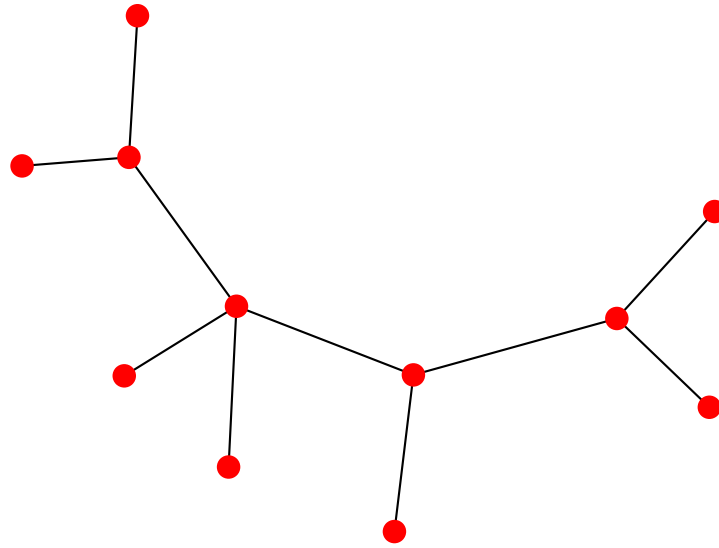


Figure 12: Force Atlas 2 layout

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