Introduction to Artificial Intelligence

Programming Assignment 3 by Boaz Bar-david and Gal Alon

In this assignment, we present a method for implementing a Bayesian network to address the Hurricane Evacuation Problem: Locate the Blockages and Evacuees. The problem involves determining the blockages of nodes and the locations of evacuees.

Our work is divided into two main parts: firstly, the design and implementation of the Bayesian network and secondly, implementation of the Enumeration algorithm to support querying.

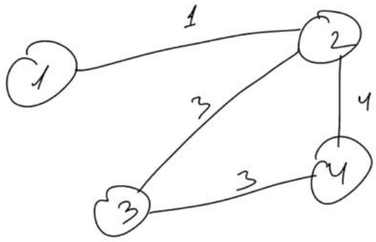
We implemented the bayes network using a graph (with the help of networkx library).
The base structure if the network is in this format:

- At the first layer we have the weather node, with a table for the probabilities of each condition.
- Below the first layer we have the blockage node (1 node for each node in the original graph), and every node has a table for its blockage state given the weather. We have a directed edge from the weather node to each of the nodes in this level.
- Lastly, the evacuees status of each node. As before each node has a table for the status of evacuees in the node given the blockage of all his neighbors (including itself). There is edge from the blockage nodes to evacuees if and only if they are neighbors in the original graph.

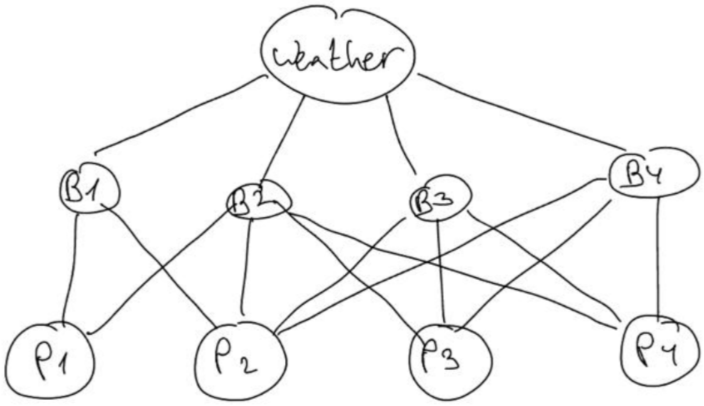
We will show the run of our program on this input:

```
#V 4        ; number of vertices n in graph (from 1 to n)

#V 1 F 0.2   ; Vertex 1, probability blockage given mild weather 0.2
#V 2 F 0.3   ; Vertex 2, probability blockage given mild weather 0.3
             ; Either assume blockage probability 0 by default,
             ; or make sure to specify this probability for all vertices.

#E1 1 2 W1 ; Edge1 between vertices 1 and 2, weight 1
#E2 2 3 W3 ; Edge2 between vertices 2 and 3, weight 3
#E3 3 4 W3 ; Edge3 between vertices 3 and 4, weight 3
#E4 2 4 W4 ; Edge4 between vertices 2 and 4, weight 4

#W 0.1 0.4 0.5 ; Prior distribution over weather: 0.1 for mild, 0.4 for stormy, 0.5 for extreme
```

The graph is:



And the bayes network:



<u>These are the probabilities tables:</u>

WEATHER:
P(mild) = 0.1
P(stormy) = 0.4
P(extreme) = 0.5

VERTEX: 1
P(blocked|mild) = 0.2
P(blocked|stormy) = 0.4
P(blocked|extreme) = 0.6000000000000001

P(people|B(1)='0', B(2)='1') = 0.8
P(people|B(1)='1', B(2)='0') = 0.7
P(people|B(1)='0', B(2)='0') = 0
P(people|B(1)='1', B(2)='1') = 0.94

VERTEX: 2
P(blocked|mild) = 0.3
P(blocked|stormy) = 0.6
P(blocked|extreme) = 0.8999999999999999

P(people|B(2)='0', B(1)='0', B(3)='0', B(4)='1') = 0.19999999999999996
P(people|B(2)='0', B(1)='0', B(3)='1', B(4)='0') = 0.3999999999999999
P(people|B(2)='0', B(1)='1', B(3)='0', B(4)='0') = 0.8
P(people|B(2)='1', B(1)='0', B(3)='0', B(4)='0') = 0.7

P(people|B(2)='0', B(1)='0', B(3)='0', B(4)='0') = 0
P(people|B(2)='0', B(1)='0', B(3)='1', B(4)='1') = 0.5199999999999999
P(people|B(2)='0', B(1)='1', B(3)='0', B(4)='1') = 0.84
P(people|B(2)='0', B(1)='1', B(3)='1', B(4)='0') = 0.88
P(people|B(2)='0', B(1)='1', B(3)='1', B(4)='1') = 0.9039999999999999
P(people|B(2)='1', B(1)='0', B(3)='0', B(4)='1') = 0.76
P(people|B(2)='1', B(1)='0', B(3)='1', B(4)='0') = 0.82
P(people|B(2)='1', B(1)='0', B(3)='1', B(4)='1') = 0.856
P(people|B(2)='1', B(1)='1', B(3)='0', B(4)='0') = 0.94
P(people|B(2)='1', B(1)='1', B(3)='0', B(4)='1') = 0.952
P(people|B(2)='1', B(1)='1', B(3)='1', B(4)='0') = 0.964
P(people|B(2)='1', B(1)='1', B(3)='1', B(4)='1') = 0.9712

VERTEX: 3
P(blocked|mild) = 0.0
P(blocked|stormy) = 0.0
P(blocked|extreme) = 0.0

P(people|B(2)='0', B(4)='1') = 0.3999999999999999
P(people|B(2)='1', B(4)='0') = 0.7
P(people|B(2)='0', B(4)='0') = 0
P(people|B(2)='1', B(4)='1') = 0.82

VERTEX: 4
P(blocked|mild) = 0.0
P(blocked|stormy) = 0.0
P(blocked|extreme) = 0.0

P(people|B(3)='0', B(2)='1') = 0.19999999999999996
P(people|B(3)='1', B(2)='0') = 0.7
P(people|B(3)='0', B(2)='0') = 0
P(people|B(3)='1', B(2)='1') = 0.76

We will show a few examples of querying in this environment given a different set of evidence:

1. evidence = {W = 'mild'}:

    What is the probability that each of the vertices contains evacuees?
    P(Ev(1) | {'W': 'mild'}) = 0.34639999999999993
    P(Ev(2) | {'W': 'mild'}) = 0.33640000000000003
    P(Ev(3) | {'W': 'mild'}) = 0.21000000000000002
    P(Ev(4) | {'W': 'mild'}) = 0.059999999999999984

    What is the probability that each of the vertices is blocked?
    P(B(1) | {'W': 'mild'}) = 0.2
    P(B(2) | {'W': 'mild'}) = 0.3

P(B(3) | {'W': 'mild'}) = 0.0
P(B(4) | {'W': 'mild'}) = 0.0

What is the distribution of the weather variable?
P(W | {'W': 'mild'}) = {'mild': 1, 'stormy': 0, 'extreme': 0}

What is the probability that a certain path (set of edges) is free from blockages?
P([2, 3, 4] is free from blockages | {'W': 'mild'}) = 0.7

2. evidence = {'W': 'stormy', 'B(1)': '1'})

   What is the probability that each of the vertices contains evacuees?
   P(Ev(1) | {'W': 'stormy', 'B(1)': '1'}) = 0.844
   P(Ev(2) | {'W': 'stormy', 'B(1)': '1'}) = 0.884
   P(Ev(3) | {'W': 'stormy', 'B(1)': '1'}) = 0.42
   P(Ev(4) | {'W': 'stormy', 'B(1)': '1'}) = 0.11999999999999997

   What is the probability that each of the vertices is blocked?
   distribution: {"['B(1)=1']": 1, "['B(1)=0']": 0}
   P(B(1) | {'W': 'stormy', 'B(1)': '1'}) = 1
   P(B(2) | {'W': 'stormy', 'B(1)': '1'}) = 0.5999999999999999
   P(B(3) | {'W': 'stormy', 'B(1)': '1'}) = 0.0
   P(B(4) | {'W': 'stormy', 'B(1)': '1'}) = 0.0

   What is the distribution of the weather variable?
   P(W | {'W': 'stormy', 'B(1)': '1'}) = {'mild': 0, 'stormy': 1, 'extreme': 0}

   What is the probability that a certain path (set of edges) is free from blockages?
   P([2, 3, 4] is free from blockages | {'W': 'stormy', 'B(1)': '1'}) = 0.4

3. evidence = {'Ev(1)': '1'}

   What is the probability that each of the vertices contains evacuees?
   distribution: {"['Ev(1)=1']": 1, "['Ev(1)=0']": 0}
   P(Ev(1) | {'Ev(1)': '1'}) = 1
   P(Ev(2) | {'Ev(1)': '1'}) = 0.8300068212824011
   P(Ev(3) | {'Ev(1)': '1'}) = 0.6247953615279673
   P(Ev(4) | {'Ev(1)': '1'}) = 0.178512960436562

   What is the probability that each of the vertices is blocked?
   P(B(1) | {'Ev(1)': '1'}) = 0.6043656207366985
   P(B(2) | {'Ev(1)': '1'}) = 0.8925648021828103
   P(B(3) | {'Ev(1)': '1'}) = 0.0
   P(B(4) | {'Ev(1)': '1'}) = 0.0

What is the distribution of the weather variable?
P(W | {'Ev(1)': '1'}) = {"['W=mild']": 0.0492269213278763, "['W=stormy']": 0.3556161891768986, "['W=extreme']": 0.5951568894952252}

What is the probability that a certain path (set of edges) is free from blockages?
P([2, 3, 4] is free from blockages | {'Ev(1)': '1'}) = 0.10743519781718966