Machine Learning:
Bayesian Network Model

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HW 3

ME 8813
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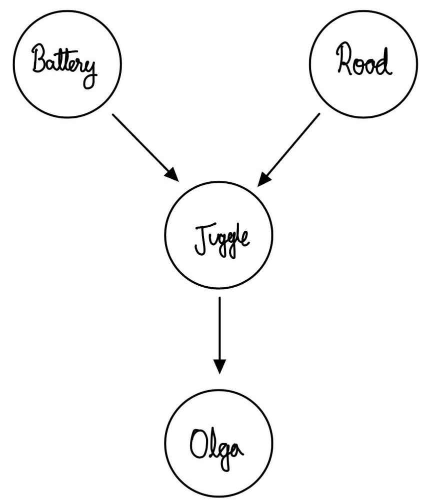
1. Introduction

In this homework, we are tasked with building a Bayesian network model using the pgmpy package. The model represents a scenario involving a juggling robot named Jason and an observer robot named Olga. The objective is to infer the probability of Jason's battery being low based on Olga's reports of Jason dropping the ball.

2. Bayesian Network Construction

The Bayesian network for the juggling model consists of four nodes: Battery, Road, Juggle, and Olga. The structure of the network and the conditional probability tables (CPTs) for each node are defined as follows:

- Battery: Represents whether the battery is charged (1) or low (0).
- Road: Represents whether the road is even (1) or uneven (0).
- Juggle: Represents whether Jason juggles successfully (1) or drops the ball (0), conditional on the battery and road states.
- Olga: Represents whether Olga observes a dropped ball (1) or does not report a dropped ball (0), conditional on whether Jason actually drops the ball.



The probability distribution tables can be seen below:

Probability distribution, P(Battery)

Battery(0)	0.05
Battery(1)	0.95

Probability distribution, P(Road)

Road(0)	0.4
Road(1)	0.6

Probability distribution, P(Juggle)

Battery	Battery(0)	Battery(0)	Battery(1)	Battery(1)
Road	Road(0)	Road(1)	Road(0)	Road(1)
Juggle(0)	0.9	0.5	0.3	0.01
Juggle(1)	0.1	0.5	0.7	0.99

Probability distribution, P(Olga)

Juggle	Juggle(0)	Juggle(1)
Olga(0)	0.1	0.9
Olga(1)	0.9	0.1

3. Independencies in the Model

The independencies in the model are listed using the get_independencies() method. The results are as follows:

(Road ⊥ Battery)
(Road ⊥ Olga | Juggle)
(Road ⊥ Olga | Juggle, Battery)
(Olga ⊥ Road, Battery | Juggle)
(Olga ⊥ Battery | Juggle, Road)
(Olga ⊥ Road | Juggle, Battery)
(Battery ⊥ Road)
(Battery ⊥ Olga | Juggle)
(Battery ⊥ Olga | Juggle, Road)

4. Exact Inference

Using the Variable Elimination algorithm for exact inference, we determine the effect on our belief that the battery is low, given that Olga reports that Jason has dropped the ball. The posterior probability calculated for the Battery node is:

P(Battery = 0 | Olga = 1) = 0.1413
P(Battery = 1 | Olga = 1) = 0.8587

This indicates that the probability of the battery being low is 14.13% when Olga reports a dropped ball.

5. Approximate Inference

Performing approximate inference using the ApproxInference method, we obtain similar results:

P(Battery = 0 | Olga = 1) = 0.1402
P(Battery = 1 | Olga = 1) = 0.8598

The results from approximate inference are very close to those obtained from exact inference, suggesting that our model is robust and consistent across different inference methods.

6. Conclusion:

The Bayesian network analysis provides insights into the relationship between Jason's battery state, road conditions, juggling performance, and Olga's reports. The low probability of the battery being low when Olga reports a dropped ball suggests that other factors, such as road conditions, might be more influential in Jason's performance. This model can be further refined and used to improve the design and monitoring of robotic systems in similar scenarios.