PROBABILISTIC REASONING ASSIGNMENTS

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LAB-1

1. What is a Bayesian classifier?

A Bayesian classifier is a type of statistical classifier based on Bayes' Theorem, which provides a way to update the probability of a hypothesis as more evidence becomes available. It's widely used in machine learning for tasks such as classification, especiallywith text data. The most well-known example is the Naive Bayes classifier.

2. Why we use a Naive Bayes Classifier? Why it is called Naive?

A Naive Bayes classifier is used because it is simple, efficient, and effective for many classification tasks, especially with high-dimensional data like text. Despite its simplicity, it can perform well in various applications such as email spam detection,sentiment analysis, and medical diagnosis.

The classifier is termed "naive" because it makes a naive assumption: it assumes thatall features are conditionally independent given the class label.

3. What are the possible advantages in choosing Naive Bayes Classifier?

- Simple and Fast: Easy to implement and quick to train, even on large datasets.
- Effective with Small Data: Works well with limited training data.
- Performs Well with High-Dimensional Data: Great for text classification andother tasks with many features.
- Handles Multi-Class Problems: Naturally supports multi-class classification.
- Interpretable: Provides clear probability estimates for each class.
- Robust to Irrelevant Features: Can perform well even with noisy or irrelevant features.

4. Prepare a classification model using Naive Bayes for the given data.

5. Consider class Fish as Y1, class Animal as Y2, and class Bird as Y3 Compute P(Y1),P(Y2), P(Y3).

6. Consider the test sample X=(Slow, Rarely, No). Predict the class label for the test sample, using the Naive Bayes classifier. (Hint: Find P(Y1/X), P(Y2/X), and P(Y3/X)).

[* Executing Qns 4 to 6 in a single code *]

CODE

```
% Data preparation
Swim = {'Fast', 'Fast', 'Slow', 'Fast', 'No', 'No', 'No', 'Slow', 'Slow', 'Slow', 'No', 'Fast'}';
Fly = {'No', 'No', 'No', 'No', 'Short', 'Short', 'Rarely', 'No', 'No', 'No', 'Long', 'No'}';
Crawl = {'No', 'Yes', 'No', 'No', 'No', 'No', 'No', 'Yes', 'No', 'Yes', 'No', 'No'}';
ClassLabel = {'Fish', 'Animal', 'Animal', 'Animal', 'Bird', 'Bird', 'Animal', 'Animal','Fish',
'Fish', 'Bird', 'Bird'}';

% Convert categorical data into numeric
categories_swim = unique(Swim);
categories_fly = unique(Fly);
categories_crawl = unique(Crawl);
categories_class = unique(ClassLabel);

Swim_int = arrayfun(@(x) find(strcmp(x, categories_swim)), Swim);
Fly_int = arrayfun(@(x) find(strcmp(x, categories_fly)), Fly); Crawl_int =
arrayfun(@(x) find(strcmp(x, categories_crawl)), Crawl);
ClassLabel_int = arrayfun(@(x) find(strcmp(x, categories_class)), ClassLabel);

% Combine data into a matrix
data = [Swim_int, Fly_int, Crawl_int, ClassLabel_int];

% Step 2: Compute Prior Probabilities P(Y1), P(Y2), P(Y3)
```

```
num_classes = length(categories_class);
priors = histc(data(:, end), 1:num_classes) / size(data, 1);
disp('Prior Probabilities:');
for c = 1:num_classes
    fprintf('P(Y%d) = %.2f\n', c, priors(c));end

% Step 3: Calculate likelihoods P(X|Y) for each feature and class
num_features = size(data, 2) - 1;
likelihoods = cell(num_classes, num_features);
for c = 1:num_classes
    class_data = data(data(:, end) == c, 1:num_features);for
    f = 1:num_features
        feature_vals = unique(data(:, f));
        likelihoods{c, f} = histc(class_data(:, f), feature_vals) / size(class_data, 1);end
end

% Test sample X = (Slow, Rarely, No)
test_sample = [find(strcmp('Slow', categories_swim)), ...
               find(strcmp('Rarely', categories_fly)), ...
               find(strcmp('No', categories_crawl))];

% Step 4: Compute posterior probabilities P(Y|X) = P(X|Y)*P(Y)/P(X)
posteriors = zeros(num_classes, 1);
for c = 1:num_classes
    posterior = priors(c);
    for f = 1:num_features
        posterior = posterior * likelihoods{c, f}(test_sample(f));
    end
```

```
    posteriors(c) = posterior;
end

% Normalize posteriors to get P(Y1|X), P(Y2|X), P(Y3|X)
posteriors = posteriors / sum(posteriors);

% Display results disp('Posterior
Probabilities:');for c =
1:num_classes
    fprintf('P(Y%d|X) = %.2f\n', c, posteriors(c));end

% Predict the class label
[~, predicted_class_idx] = max(posteriors); predicted_class
= categories_class{predicted_class_idx};
fprintf('Predicted class for the test sample is: %s\n', predicted_class);
```

```
octave:12> source("mat_lab1.m")
Prior Probabilities:
P(Y1) = 0.42
P(Y2) = 0.33
P(Y3) = 0.25
Posterior Probabilities:
P(Y1|X) = 1.00
P(Y2|X) = 0.00
P(Y3|X) = 0.00
Predicted class for the test sample is: Animal
```

LAB-2

```
# Install the required library
!pip install pgmpy
```

```
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```
# Install pgmpy and supporting libraries
!pip install pgmpy networkx matplotlib
```

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```

```
from pgmpy.models import BayesianNetwork

# Step 1: Define the Bayesian Network
structuremodel = BayesianNetwork([
    ('Diff', 'Grade'), # Difficulty influences Grade
    ('Intel', 'Grade'), # Intelligence influences Grade
    ('Grade', 'Letter'),# Grade influences Letter
    ('Intel', 'SAT')])  # Intelligence influences SAT
```

```
# Step 2: Define the CPDs (Conditional Probability

Distributions)from pgmpy.factors.discrete import TabularCPD

# CPD for Difficulty
cpd_diff = TabularCPD(variable='Diff', variable_card=2,
                      values=[[0.6], [0.4]],
                      state_names={'Diff': ['Easy', 'Hard']})

# CPD for Intelligence
cpd_intel = TabularCPD(variable='Intel', variable_card=2,
                       values=[[0.7], [0.3]],
                       state_names={'Intel': ['Dumb', 'Intelligent']})

# CPD for Grade
cpd_grade = TabularCPD(variable='Grade', variable_card=3,
                       values=[
                           [0.3, 0.05, 0.9, 0.5],   # Grade A (G=0)
                           [0.4, 0.25, 0.08, 0.3], # Grade B (G=1)
                           [0.3, 0.7,   0.02, 0.2]   # Grade C (G=2)
                       ],
                       evidence=['Intel', 'Diff'], evidence_card=[2, 2],
```

```
                        state_names={'Grade': ['A', 'B', 'C'], 'Intel': ['Dumb', 'Intelligent'], 'Diff': ['Easy', 'Hard']})

# CPD for SAT
cpd_sat = TabularCPD(variable='SAT', variable_card=2,
                     values=[
                         [0.95, 0.2],   # SAT Bad (S=0)
                         [0.05, 0.8]     # SAT Good (S=1)
```

```
                        ],
                        evidence=['Intel'], evidence_card=[2],
                        state_names={'SAT': ['Bad', 'Good'], 'Intel': ['Dumb', 'Intelligent']})

# CPD for Letter
cpd_letter = TabularCPD(variable='Letter', variable_card=2,
                            values=[
                                [0.1, 0.4, 0.99],   # Letter Bad (L=0)
                                [0.9, 0.6, 0.01]      # Letter Good (L=1)
                            ],
                            evidence=['Grade'], evidence_card=[3],
                            state_names={'Letter': ['Bad', 'Good'], 'Grade': ['A', 'B', 'C']})
# Add CPDs to the
model


model.add_cpds(cpd_diff, cpd_intel, cpd_grade, cpd_sat, cpd_letter)

# Validate the model
assert model.check_model()

print("CPDs:")
print(cpd_diff)
print(cpd_intel
)
print(cpd_grad
e)
print(cpd_sat)
print(cpd_letter)
```

```
CPDs:
+------------+-----+
| Diff(Easy) | 0.6 |
+------------+-----+
| Diff(Hard) | 0.4 |
+------------+-----+
+--------------------+-----+
| Intel(Dumb)                | 0.7 |
+--------------------+-----+
| Intel(Intelligent) | 0.3 |
+--------------------+-----+
+----------+-------------+-------------+--------------------+--------------------+
| Intel          | Intel(Dumb) | Intel(Dumb) | Intel(Intelligent) | Intel(Intelligent) |
+----------+-------------+-------------+--------------------+--------------------+
| Diff           | Diff(Easy)  | Diff(Hard)  | Diff(Easy)                      | Diff(Hard)                  |
+----------+-------------+-------------+--------------------+--------------------+
| Grade(A) | 0.3                    | 0.05              | 0.9                        | 0.5                         |
+----------+-------------+-------------+--------------------+--------------------+
| Grade(B) | 0.4                    | 0.25              | 0.08                       | 0.3                         |
+----------+-------------+-------------+--------------------+--------------------+
| Grade(C) | 0.3                    | 0.7               | 0.02                       | 0.2                         |
+----------+-------------+-------------+--------------------+--------------------+
+-----------+-------------+--------------------+
| Intel           | Intel(Dumb) | Intel(Intelligent) |
+-----------+-------------+--------------------+
| SAT(Bad)  | 0.95                 | 0.2                          |
+-----------+-------------+--------------------+
| SAT(Good) | 0.05                 | 0.8                          |
+-----------+-------------+--------------------+
+--------------+----------+----------+----------+
| Grade               | Grade(A) | Grade(B) | Grade(C) |
+--------------+----------+----------+----------+
| Letter(Bad)  | 0.1                 | 0.4           | 0.99           |
+--------------+----------+----------+----------+
| Letter(Good) | 0.9                 | 0.6           | 0.01           |
+--------------+----------+----------+----------+
```

```
# Step 3: Local independencies and active trail nodes# Local
Independencies
print("Local Independencies:")
print(model.local_independencies('Diff'))
print(model.local_independencies('Intel'))
```

```
print(model.local_independencies('Grade'))
print(model.local_independencies('SAT'))
print(model.local_independencies('Letter'))

# Active trail nodes for 'Diff'
print("\nActive trail nodes for 'Diff':")
print(model.active_trail_nodes('Diff'))
```

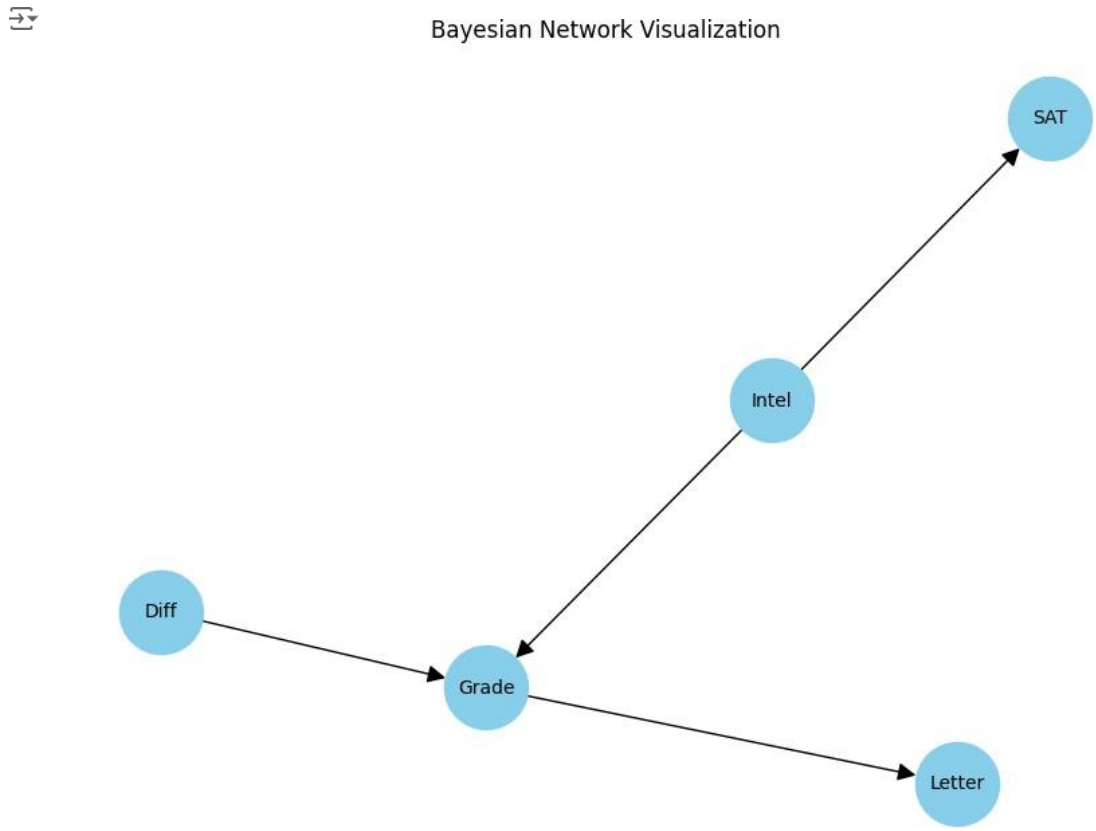
```
Local Independencies:(Diff ⊥
SAT, Intel) (Intel ⊥ Diff)
(Grade ⊥ SAT | Diff, Intel)
(SAT ⊥ Diff, Grade, Letter | Intel)(Letter ⊥ SAT,
Diff, Intel | Grade)

Active trail nodes for 'Diff':
{'Diff': {'Diff', 'Grade', 'Letter'}}
```

```
# Step 4: Visualize the Bayesian Networkimport
networkx as nx
import matplotlib.pyplot as plt

# Manually convert the BayesianNetwork into a networkx graph graph =
nx.DiGraph() # Directed graph for Bayesian networksfor edge in model.edges():
    graph.add_edge(edge[0], edge[1])

# Visualize the graph using networkx
plt.figure(figsize=(8, 6))
nx.draw(graph, with_labels=True, node_color="skyblue", font_size=10, node_size=2000, edge_color="black", arrowsize=20)plt.title("Bayesian Network
Visualization")
plt.show()
```

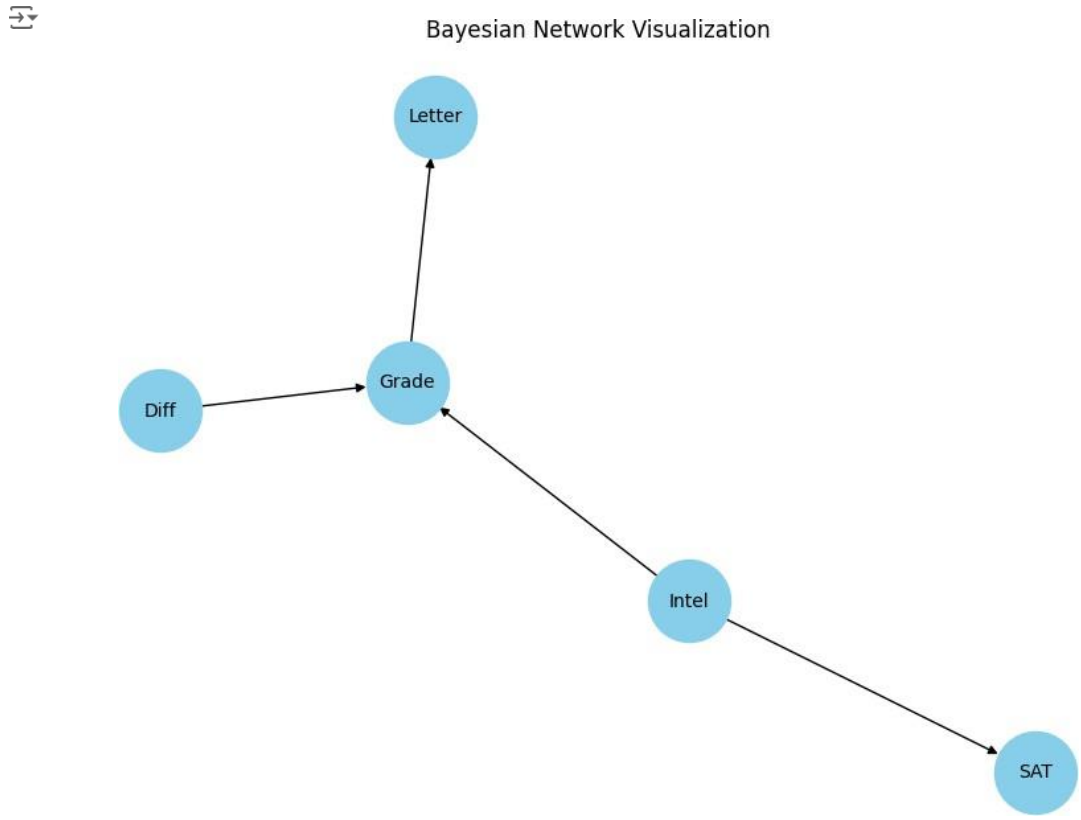



```
import networkx as nx
import matplotlib.pyplot as plt

# Create a directed graph using networkxgraph =
nx.DiGraph()

# Add nodes and edges from the Bayesian Network
graph.add_nodes_from(model.nodes())
graph.add_edges_from(model.edges())

# Visualize the graph using networkx
plt.figure(figsize=(8, 6))
nx.draw(graph, with_labels=True, node_color="skyblue", font_size=10, node_size=2000, edge_color="black")plt.title("Bayesian Network
Visualization")
plt.show()
```


Bayesian Network Visualization
Letter
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LAB-3

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```
# Install the pgmpy library
!pip install pgmpy
```

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   2.0/2.0 MB 17.6 MB/s eta 0:00:00Installing collected packages: pgmpy
```

```
# Import necessary modules
from pgmpy.models import MarkovNetwork
from pgmpy.factors.discrete import DiscreteFactorfrom
pgmpy.inference import VariableElimination

# Step 1: Define the Markov Network# Create
an empty Markov Network
model = MarkovNetwork()

# Add edges as per the network structure from the table
model.add_edges_from([('A', 'B'), ('B', 'C'), ('C', 'D'), ('D', 'A')])

# Step 2: Add the Factors# Factor
ϕ(A, B)
phi_AB = DiscreteFactor(
    variables=['A', 'B'],
```

```
        cardinality=[2, 2], # Binary variablesvalues=[
            [30, 5], # A=0, B=0 | A=0, B=1[1, 10] #
            A=1, B=0 | A=1, B=1
        ]
)

# Factor ϕ(B, C)
phi_BC = DiscreteFactor(
        variables=['B', 'C'],
        cardinality=[2, 2], values=[
            [100, 1], # B=0, C=0 | B=0, C=1[1, 100]
                        # B=1, C=0 | B=1, C=1
        ]
)

# Factor ϕ(C, D)
phi_CD = DiscreteFactor(
        variables=['C', 'D'],
        cardinality=[2, 2], values=[
            [1, 100], # C=0, D=0 | C=0, D=1[100, 1]
                        # C=1, D=0 | C=1, D=1
        ]
)

# Factor ϕ(D, A)
phi_DA = DiscreteFactor(
        variables=['D', 'A'],
        cardinality=[2, 2], values=[
            [100, 1], # D=0, A=0 | D=0, A=1[1, 100]
                        # D=1, A=0 | D=1, A=1
        ]
)

# Add these factors to the model
model.add_factors(phi_AB, phi_BC, phi_CD, phi_DA)

# Step 3: Perform inference
inference = VariableElimination(model)

# Example query: MAP estimation for variable 'C' given evidence A=0 and B=1result =
inference.map_query(variables=['C'], evidence={'A': 0, 'B': 1})
print("\nMAP Query result (C given A=0, B=1):")print(result)

# Example query: Probability of 'C' given evidence
prob_result = inference.query(variables=['C'], evidence={'A': 0, 'B': 1})print("\nProbability
distribution of 'C' given A=0, B=1:")
print(prob_result)
```

```
Eliminating: D: 100%                                                    1/1 [00:00<00:00,  63.14it/s]

MAP Query result (C given A=0, B=1):
{'C': 1}

Probability distribution of 'C' given A=0, B=1:
+------+--------------+
| C          |               phi(C) |
+=======+===============+
| C(0) |              1000.0000 |
+------+--------------+
| C(1) | 5000500.0000 |
+------+--------------+
```