CS 429/529
Introduction to Machine Learning.
Cenek. Fall 2020
Week 10 Lab 7 – Probabilistic ML.
Due: 11/8/2020 NLT Midnight

NAMES:____

In this lab, you will solve several problems using probabilistic machine learning models.

1. Simple statistics using priors and Bayes rule.

In the CS department, the ration of students who get internship before graduating and those who don't is about 62 and 38 percent. As many students in the CS department don't have a job while they go to school, the number of students who don't have an internship but have a job is pretty small, only 12 percent. We randomly asked Pluto, a CS student, if he had a job. The answer was no. What is the probability that Pluto has an internship?

h_1 = Student has internship
h_2 = Student does not have internship
D = Pluto does not have a job

$P(h_1) =$
$P(h_2) =$

$P(D \mid h_1) =$
$P(D \mid h_2) =$

$P(D) =$

$P(h_1 \mid D) =$

2. Naive Bayes Classifier.
The following data was collected about a race car driver Piggie. Piggie's Performance on the race track was rated as either <u>fast</u> or <u>slow</u> based on the different observations. The observations were made over several days and include the status of her race engine: CarEngine being <u>warm</u> or <u>cold</u>, weather he took the race course practice runs: CoursePractice being <u>yes</u> or <u>no</u>, and the current condition of the race track: Condition being <u>dry</u> or <u>wet</u>.

Train a simple Naive Bayes Classifier that is trained on the following data and classify an unknown data point. The unknown datapoint are observations made about Piggy and the classification will be if she will be fast or slow on the track.

Training Data

Observation	CarEngine	CoursePractice	Condition	Performance
1	Cold	Yes	Wet	Slow

2	Warm	Yes	Dry	Fast
3	Warm	No	Dry	Fast
4	Warm	Yes	Dry	Fast
5	Warm	No	Dry	Fast
6	Cold	No	Wet	Slow

The following observations was made, what will be Piggie's performance?

X1	Warm	Yes	Wet	?
X2	Cold	No	Wet	?

Please show your intermediate calculations you had to do to calculate the classification of the X1 and X2 datapoints. Please clearly label your calculations such as P(CarEngine = cold | fast) = ...

P(X1 = fast) =
P(X1 = slow) =

P(X2 = fast) =
P(X2 = slow) =

Please don't forget to write your answers into the table 2 as either Slow or Fast.

3. Gaussian Naive Classifier.
Dealing with categorical data in question 1 was pretty easy, but we did not want limit ourselves to binary observations. We asked the race track staff to record accurate data about the observations and use a ternary performance label: fast, slow and medium.
The following is information about Goofy's observation and performance. Notice that the observed data in each column was normalized to 0-1 range:

Training Data

Observation	f1=CarEngine(temp)	f2=CoursePractice(time)	f3=Condition(%)	R=Performance
1	.3	.6	.2	Slow
2	.2	.4	.4	Fast
3	.4	.9	.6	Medium
4	.2	.8	.9	Medium
5	.9	.4	.8	Fast
6	.4	.1	.7	Slow

a.)
Train a Gaussian Bayes Classifier on the above data and calculate the μ σ Gaussian parameters for all three performance labels (Fast, Medium, Slow). Also calculate the probability of each performance

label occurring in the data. You should have calculated values for the following parameters: $\mu_{f1, fast}$, $\sigma_{f1, fast}$, $\mu_{f1, medium}$, $\sigma_{f1, medium}$, $\mu_{f1, slow}$, $\sigma_{f1, slow}$, $\mu_{f2, fast}$, $\sigma_{f2, fast}$, $\mu_{f2, medium}$, $\sigma_{f2, medium}$, $\mu_{f2, slow}$, $\sigma_{f2, slow}$, $\mu_{f3, fast}$, $\sigma_{f3, fast}$, $\mu_{f3, medium}$, $\sigma_{f3, medium}$, $\mu_{f3, slow}$, $\sigma_{f3, slow}$, P(R=slow), P(R=medium), P(R=slow).
Please show your work.

b.) A new data of Goofy's performance came in. What should be his performance on the track? Calculate the probability each label being assigned to the unknown measurements X1 and X2

X1	.2	.9	.9	?
X2	.3	.1	.2	?

i. Now, use the model you trained in the above step. First, calculate the Probability Distribution Function (PDF) value for each of the measurement in each datapoint X1 and X2 above for each performance label. For the X1 point, you should end up with calculated values for each of the PDF(f1=.2|R=fast), PDF(f1=.2|R=slow), PDF(f1=.2|R=medium), PDF(f2=.9|R=fast), PDF(f2=.9|R=slow), PDF(f2=.9|R=medium), P(f3=.9|R=fast), PDF(f3=.9|R=slow), PDF(f3=.9|R=medium). (repeat the same for the point X2). Please show your work.

ii. The final step is to combine the individual PDFs for each label, weight them with the relevant label probability and calculate the probability of each data point having each label. You should end up with values for each datapoint. For X1, you should have P(R=fast|X1), P(R=medium|X1), P(R=slow|X1) (repeat the process for the point X2). Circle the largest probability – that's the label assigned to the datapoint. Don't forget to write in your answer to the above table 2. Please show your work.

4. Hidden Markov Models.
Let's simplify one of the lecture examples of a Mars Rover and build a hidden Markov model that will detect if the UPRover is moving or not. The UPRover, has only two sensors (S) one on each side of its body. Please note that the sensors might not be reporting correctly and the sensor value reported is the raw voltage not velocity. The UPRover is autonomous and does not have a camera, so there is no way to manually check if the rover is moving or not.

Before we let he rover roam, we collected some basic statistics.
P(A= moving) = 0.95
P(A=¬ moving) = 0.05

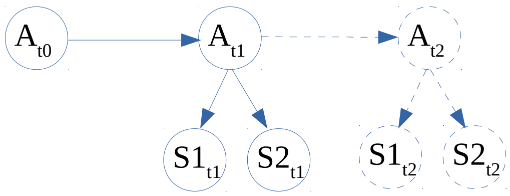
Transitions	P(A= moving)	P(A=¬ moving)
P(A= moving)	0.92	0.34
P(A=¬ moving)	0.08	0.66

Measured observations about the two on-board sensors P(X|S):

Observations	S1	S2
A= moving	0.69	0.73

A=¬ moving	0.22	0.18

The above scenario can be described as a following Hidden Markov Model:



Use the above initial measurements and apply the dynamic Hidden Markov Model algorithm to calculate the conditional probability that the UPRover is moving. Repeat the HMM algorithm to calculate the probability for, A_{t2}, A_{t3}, A_{t4}. Using only one previous state to calculate the prior. In other words, to predict the A_{t1} use , A_{t0} and $S1_{t1}$ and $S2_{t1}$ readings. For calculation of the A_{t2} use , A_{t1} and $S1_{t2}$ and $S2_{t2}$ readings etc.

Please show your work for the computation in the following steps steps

i.MHH step1: Calculate A_{t1} and assume that the UP rover was moving at the initial state $A_{t0.}$

ii. MHH step2: Update the state A_{t1} for the sensor observations that came in as $S1_{t1}$= 0.4 and $S2_{t1}$= 0.6

iii.MHH step1: Calculate prediction for A_{t2} using previous predictions and observations using one previous state.

iv. MHH step2: Update the state A_{t2} for the sensor observations that came in as $S1_{t2}$= 0.9 and $S2_{t2}$= 0.8

v. MHH step1: Calculate prediction for A_{t3} using previous predictions and observations using one previous state.

vi. MHH step2: Update the state A_{t3} for the sensor observations that came in as $S1_{t3}$= 0.01 and $S2_{t3}$= 0.2

vii. MHH step1: Calculate prediction for A_{t4} using previous predictions and observations using one previous state.

viii. MHH step2: Update the state A_{t4} for the sensor observations that came in as $S1_{t4}$= 0.02 and $S2_{t4}$= 0.12

Submit a pdf of this lab worksheet and your source code for question 2 on Moodle NLT due date.