TEAM ID : H24 MEMBER : Yujin Kim, ykim68

ALDA Fall 2025
HW3
Due: 09/25/2025

HW3 contains 3 questions. Please read and follow the instructions.

- **DUE DATE FOR SUBMISSION: 09/25/2024 11:45 PM**
- **TOTAL NUMBER OF POINTS: 70**
- **NO PARTIAL CREDIT** will be given so provide concise answers.
- **Submissions and updates should be handled by the same person.**
- **You MUST manually add ALL team members in the submission portal when you submit through Gradescope. One submission per group. Team member(s) who are left out will lose 20 points if added after the deadline.**
- Make sure you clearly list **your homework team ID, all team members' names, and Unity IDs, for those who have contributed to the homework contribution** at the top of your submission.

https://github.com/ykim68ncstate/ncsu-engr-ALDA-Fall2025-H24

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[GradeScope and GitHub Submission Instructions for Coding Questions]: For coding questions, you must submit your written solutions as a PDF on GradeScope and also provide your code in a private GitHub repository with instructor access.

1. **Create a private GitHub repository for your group.** Name your repository using the following format:

   `ncsu-engr-ALDA-Fall2025-HXX`

   Replace `XX` with your homework group number. **Example:** `ncsu-engr-ALDA-Fall2025-H2`. You will use one homework repository for the whole semester: do not create a new repository for each homework.
2. **Set up the repository:**
   - Log in to GitHub and click the green **"New"** button.
   - Use the required naming convention.
   - Set the repository to **private**.
   - Click **"Create repository"**.
3. **Add collaborators:**
   - Navigate to **Settings** > **Collaborators**.
   - Add all group members.
   - **Add the instructors and TAs.**
4. **Organize your code:**
   - Create separate folders for each of five assignments (e.g., `HW1`, `HW2`, etc.).
   - Place all relevant code in the correct folder.
   - Upload your complete `.py` files **before the submission deadline**. Late or missing code will not be graded.
5. **Include your GitHub repository link in the GradeScope PDF.**
6. **Clearly reference your code in the PDF:**
   - Indicate the relevant file for each question.
     Example: "The solution to Question 2 is in `matrix.py`."
   - Code must be executable; outputs must be generated by running the file.
   - **Do not hardcode results.** Submissions without proper computation will receive no credit.
7. **Code excerpts and outputs:** Your PDF must include output for each part and key code snippets (not full scripts) that demonstrate your implementation logic.

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1. (16 points) [**Coding - KNN + CV**] [**Graded by Rajesh Debnath**] Considering the dataset with two real-valued inputs $x1$ and $x2$ and one binary output y in the table below. Each data point will be referred using the first column "ID" in the following. You will use KNN with Euclidean distance to predict y.

   Follow the instructions under "GradeScope and GitHub Submission Instructions for Coding Questions" (see page 2). Write code in Python to perform the following tasks; if needed, you are allowed to use `scipy`, `sklearn`, and `numpy` packages. Please submit one code file via the NCSU GitHub repository you have been given. **Show your work. Show steps for reaching the answer.**

ID	x1	x2	y
1	-2	4.0	⋆
2	-6.48	5.0	♠
3	0.93	-2.0	⋆
4	0.2	2.0	♠
5	1.69	2.0	⋆
6	-5.85	4.0	⋆
7	3.0	0.0	♠
8	-0.36	8.0	♠
9	-1.68	3.0	♠
10	0.0	0.0	⋆

   (a) (4 points) What is the leave-one-out cross-validation error of 1NN on this dataset? 0.9

   (b) (2 points) What are the 3 nearest neighbors for data points 2 and 8 respectively. ID2 = (6, 1.1819)★ / (1, 4.5902)★ / (9, 5.2)♠ , ID8 = (1, 4.3231)★ / (9, 5.1713)♠ / (4, 6.026)♠

   (c) (5 points) What is the 3-folded cross-validation error of 3NN on this dataset? For the ith fold, the testing dataset is composed of all the data points whose (ID mod $3 = i - 1$). 0.7

   (d) (5 points) Based on the results of (a) and (c), can we determine which is a better classifier, 1NN or 3NN? Why? (Answers without a correct justification will get zero points.)

   In this dataset, the leave-one cross validation error of 1NN is 0.9, whereas the 3-fold cross validation error of 3NN is 0.7, so 3NN achieve the lower error. Because 3NN averages over neighbors via majority vote, it is less sensitive to noise/outliers and typically reduces variance, which can yield better generalization on small samples. However, since (a) and (c) use different cross validation protocols, the comparison is not fully fair, for a fair assessment we should evaluate both 1NN and 3NN under the same cross validation scheme with identical folds.

KNN+CV

```python
from sklearn.neighbors import NearestNeighbors
import numpy as np
import pandas as pd
df = pd.read_csv("HW3_data/cv+knn.csv")

print(df)
```

```
   ID    x1   x2      y
0   1 -2.00  4.0   star
1   2 -6.48  5.0  spade
2   3  0.93 -2.0   star
3   4  0.20  2.0  spade
4   5  1.69  2.0   star
5   6 -5.85  4.0   star
6   7  3.00  0.0  spade
7   8 -0.36  8.0  spade
8   9 -1.68  3.0  spade
9  10  0.00  0.0   star
```

```python
X = df[['x1', 'x2']].values
y = df['y'].values
```

(a) What is the leave-one-out cross-validation error of 1NN on this dataset?

```python
from sklearn.model_selection import LeaveOneOut
from sklearn.neighbors import KNeighborsClassifier

loo = LeaveOneOut()
errors = 0

for train_index, test_index in loo.split(X):
    X_train, X_test = X[train_index], X[test_index]
    y_train, y_test = y[train_index], y[test_index]

    knn = KNeighborsClassifier(n_neighbors=1)
    knn.fit(X_train, y_train)
    y_prediction = knn.predict(X_test)

    if y_prediction[0] != y_test[0]:
        errors += 1

loo_error_rate = errors / len(X)
print(f"LOOCV 1NN Error: {loo_error_rate:.3f}")
#https://scikit-learn.org/stable/modules/generated/sklearn.neighbors.KNeighborsClassifier.html
```

✓ 0.0s

```
LOOCV 1NN Error: 0.900
```

https://github.com/ykim68ncstate/ncsu-engr-ALDA-Fall2025-H24

(b) What are the 3 nearest neighbors for data points 2 and 8 respectively.

```
ids = df['ID'].values

nbrs = NearestNeighbors(n_neighbors=4, algorithm='ball_tree', metric='euclidean').fit(X)
distance, indices = nbrs.kneighbors(X)

#https://scikit-learn.org/stable/modules/neighbors.html

def three_nbrs_for_id(target_id):
    i = np.where(ids == target_id)[0][0]
    neighbors_indices = indices[i][1:4]
    return list(zip(ids[neighbors_indices], distance[i][1:4], y[neighbors_indices]))

nbrs_2 = three_nbrs_for_id(2)
nbrs_8 = three_nbrs_for_id(8)

print("3 nearest neighbors for ID=2:", nbrs_2)
print("3 nearest neighbors for ID=8:", nbrs_8)
```

✓ 0.0s

(c) What is the 3-folded cross-validation error of 3NN on this dataset?

For the ith fold, the testing dataset is composed of all the data points whose (ID mod 3 = i-1).

```
errors = 0
total = 0

for i in [1, 2, 3]:
    test_mask = (ids % 3) == (i - 1)
    train_mask = ~test_mask

    X_train, X_test = X[train_mask], X[test_mask]
    y_train, y_test = y[train_mask], y[test_mask]

    knn3 = KNeighborsClassifier(n_neighbors = 3, algorithm = 'ball_tree', metric = 'euclidean')
    knn3.fit(X_train, y_train)

    y_pred = knn3.predict(X_test)

    fold_error = np.sum(y_pred != y_test)
    errors += fold_error
    total += len(y_test)

CrossValidation3fold_error_rate = errors / total
print(f"3-folded cross validation Error: {CrossValidation3fold_error_rate:.3f}")
```

✓ 0.0s

```
3-folded cross validation Error: 0.700
```

2. (30 points) [**Adaboost**] [**Graded by Ian Holmes**] Consider the labeled data points in Figure 1, where '+' and '-' indicate class labels. We will use AdaBoost with Separating Hyperplane to train a classifier for the '+' and '-' labels. Each boosting iteration will select a horizontal or vertical Separating Hyperplane: **a vertical or horizontal line** that would split the space into half-spaces with a goal of minimizing the weighted training error. Breaking ties by choosing '+'. All of the data points start with uniform weights. Please display your answers for (a), (b), (d) and (e) in a single figure.

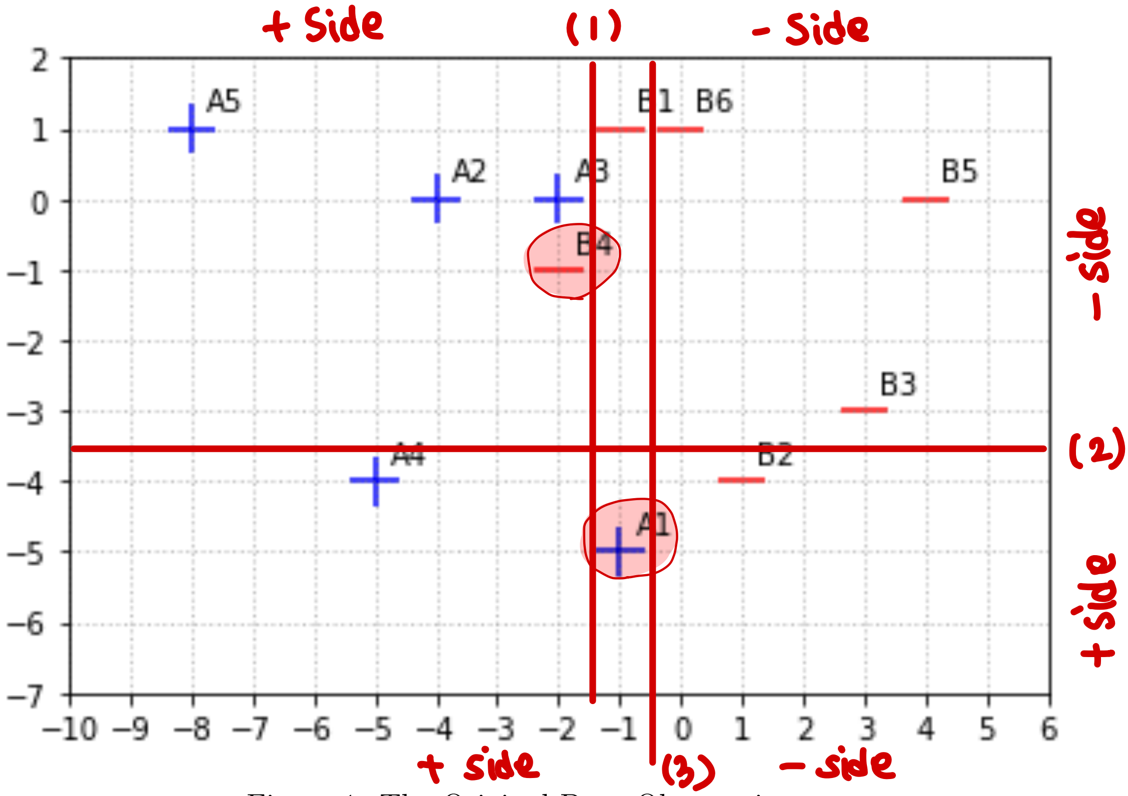


Figure 1: The Original Data Observations.

(a) (4 points) In Figure 1, draw a decision boundary corresponding to the first decision stump that the algorithm would choose (the decision boundary should be either a vertical or horizontal straight line). Label the decision boundary as (1), also indicate the '+' / '-' sides of this boundary.

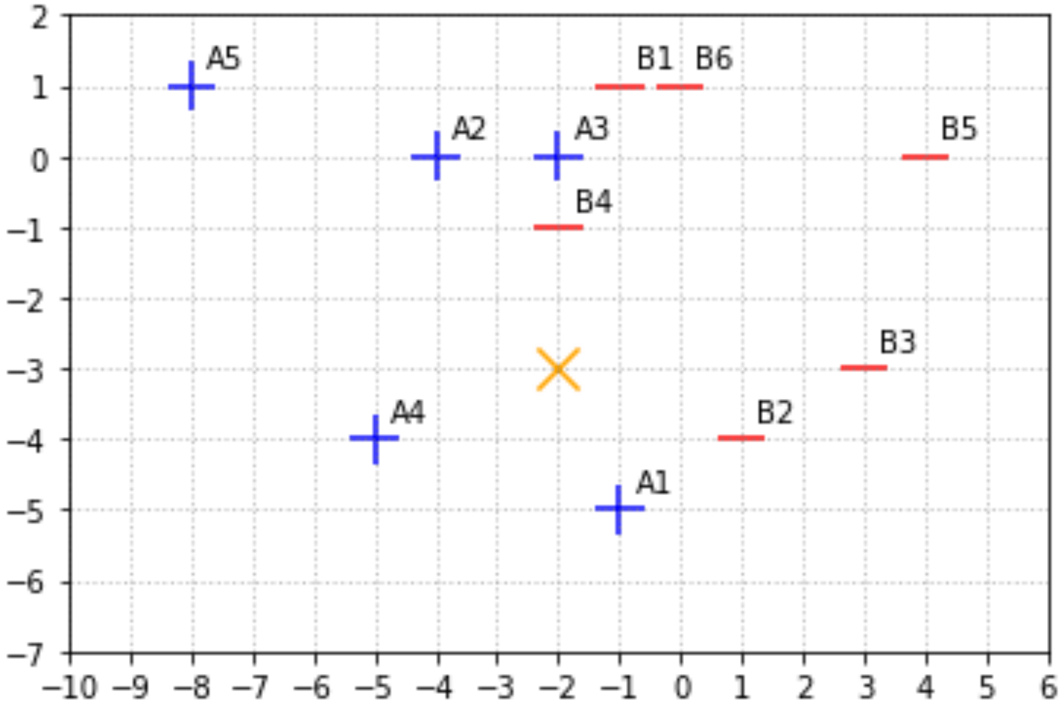
(b) (3 points) Circle the point(s) that have the highest weight after the first boosting iteration. Also, report the value of the highest weight and show your calculations.

(c) (6 points) After the labels have been re-weighted in the first boosting iteration, what is the weighted error of the decision boundary (1)?

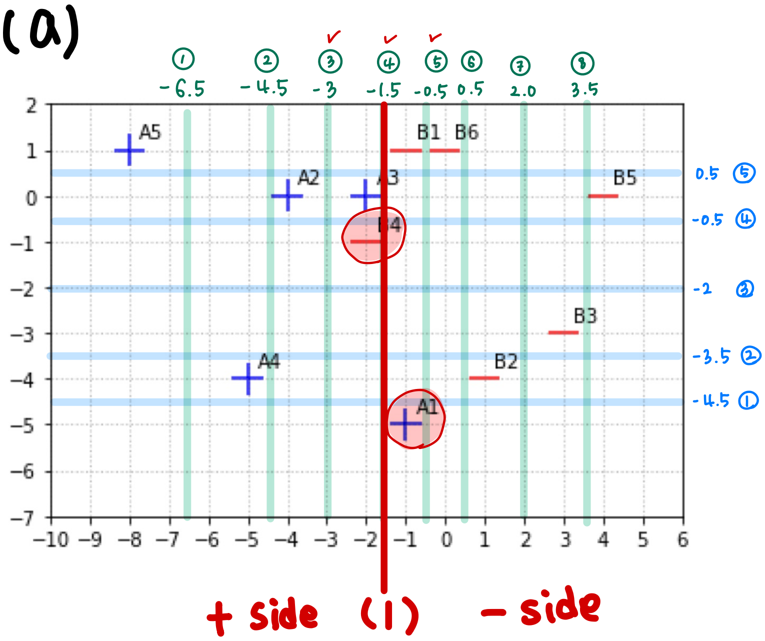
(d) (4 points) Draw the decision boundary corresponding to the second decision stump that the algorithm would choose. Label the decision boundary as (2), also indicate the '+' / '-' sides of this boundary.

(e) (6 points) Next, compute the weighted error of the decision boundary (2) and draw a decision boundary corresponding to the third decision stump that the algorithm would choose. Label the decision boundary as (3), also indicate the '+' / '-' sides of this boundary.

(f) (7 points) Assuming that a "New Data point" is given (shown in the graph below), using your classifier built from decision boundaries (1), (2) and (3) to predict the class label for the new data point. Provide your final classifier along with the class label. Show your work.



(a)



Vertical ▶
① error = 4
② error = 3
③ error = 2
④ error = 2
⑤ error = 2
⑥ error = 3
⑦ error = 4
⑧ error = 5

Horizontal ▲
① error = 4
② error = 4
③ error = 5
④ error = 6
⑤ error = 5

(b)

$n = 11 \qquad W_n^{(1)} = 1/11 \qquad \varepsilon_1 = 2/11$

$\alpha_1 = \frac{1}{2}\ln\frac{1-\varepsilon_1}{\varepsilon_1} = \frac{1}{2}\ln\frac{9/11}{2/11} = \frac{1}{2}\ln\frac{9}{2} \rightarrow e^{\alpha_1} = \sqrt{\frac{9}{2}} = \frac{3}{\sqrt{2}}, \quad e^{-\alpha_1} = \frac{\sqrt{2}}{3}$

$Z_1 = \frac{9}{11}\cdot\frac{\sqrt{2}}{3} + \frac{2}{11}\cdot\frac{3}{\sqrt{2}} = \frac{3\sqrt{2}}{11} + \frac{3\sqrt{2}}{11} = \frac{6\sqrt{2}}{11}$

Wrong Weight : $w_{n_w}^{(2)} = \frac{W_n^{(1)}}{Z_1} \times e^{\alpha_1} = \frac{1}{11}\times\frac{11}{6\sqrt{2}}\times\frac{3}{\sqrt{2}} = \frac{1}{4}$ → Max weight : A_1, B_4

Correct Weight : $W_{n_c}^{(2)} = \frac{W_n^{(1)}}{Z_1} \times e^{-\alpha_1} = \frac{1}{11}\times\frac{11}{6\sqrt{2}}\times\frac{\sqrt{2}}{3} = \frac{1}{18}$

(C)

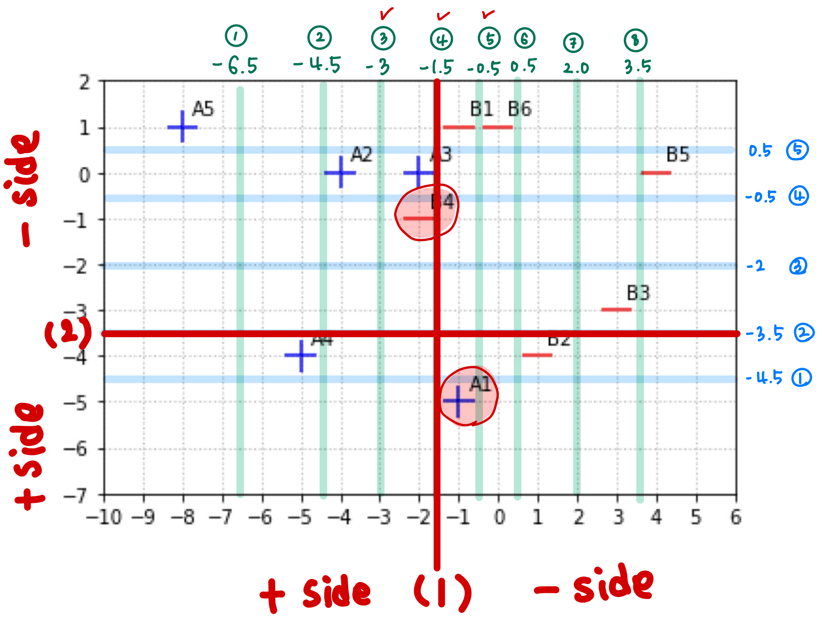
wrong data point : $A_1(+)$, $B_4(-)$

$\varepsilon_1 = \frac{2}{11} \quad \alpha_1 = \frac{1}{2}\ln\frac{9}{2} \quad Z_1 = \frac{6\sqrt{2}}{11}$

$\varepsilon_1' = \sum_{n=1}^{N} W_n^{(2)} I(f_1(x_n) \neq y_n) = W_{A_1}^{(2)} + W_{B_4}^{(2)} = \frac{1}{4} + \frac{1}{4} = 0.5$

$\varepsilon_1' = 0.5$

(d)



horizontal

Classify A_1 and B_4

(2-1) error (▼+) = 4 , A_1 : 0 , B_4 : 0

+ error : 4

- error : 0

(2-2) error (▼+) = 4, A_1 : 0, B_4 : 0

+ error : 3

- error : 1

(e)

Wrong classified data points : A_1, B_4 : $\alpha = \frac{1}{4}$

others (9EA) = $\frac{1}{18}$

$y = -3.5$ → wrong data points : A_2, A_3, A_5, B_2 → b

$$\varepsilon_2 = 4b = \frac{4}{18} = \frac{2}{9}$$

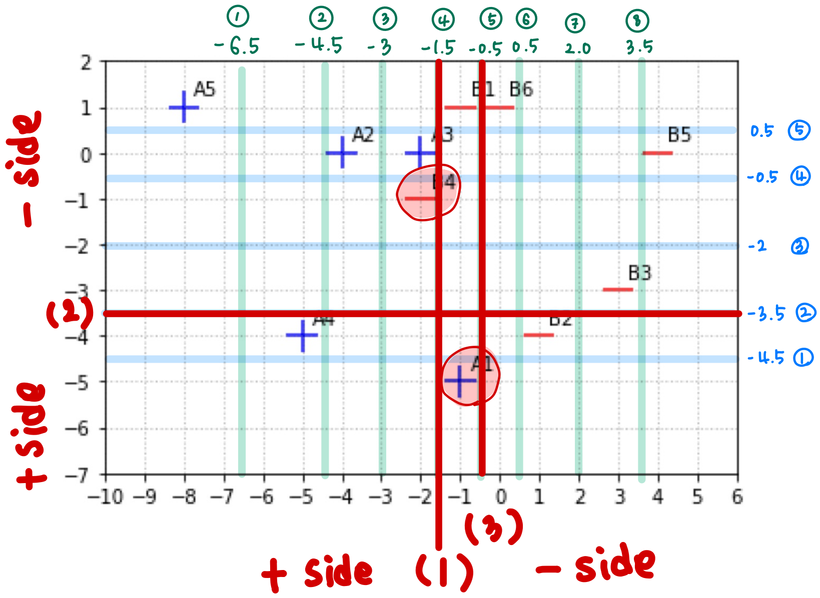
$$\alpha_2 = \frac{1}{2}\ln\frac{1-\varepsilon_2}{\varepsilon_2} = \frac{1}{2}\ln\frac{7/9}{2/9} = \frac{1}{2}\ln\frac{7}{2} \rightarrow e^{\alpha_2} = \sqrt{\frac{7}{2}}, \; e^{-\alpha_2} = \sqrt{\frac{2}{7}}$$

$$Z_2 = \frac{2}{9} \times \frac{\sqrt{7}}{\sqrt{2}} + \frac{7}{9} \times \frac{\sqrt{2}}{\sqrt{7}} = \frac{\sqrt{14}}{9} + \frac{\sqrt{14}}{9} = \frac{2\sqrt{14}}{9}$$

$$W_{nw}^{(3)} = \frac{W_n^{(2)}}{Z_2} \times e^{\alpha_1} = \frac{1}{18} \cdot \frac{9}{2\sqrt{14}} \times \frac{\sqrt{7}}{\sqrt{2}} = \frac{1}{8} \quad \rightarrow A_2, A_3, A_5, B_2$$

$$W_{nc\_oth}^{(3)} = \frac{W_n^{(2)}}{Z_2} \times e^{-\alpha_1} = \frac{1}{18} \times \frac{9}{2\sqrt{14}} \times \frac{\sqrt{2}}{\sqrt{7}} = \frac{1}{28} \quad \rightarrow A_4, B_1, B_3, B_5, B_6$$

$$W_{n\_A1B4}^{(3)} = \frac{W_{nw}^{(2)}}{Z_2} \times e^{-\alpha_1} = \frac{1}{4} \times \frac{9}{2\sqrt{14}} \times \frac{\sqrt{2}}{\sqrt{7}} = \frac{9}{56} \quad \rightarrow A_1, B_4$$



Minimum error (x, y)

(3-1) $x = -3$ (2EA)

+error : 2 (A_1, A_3)

- error : 0

(3-2) $x = -0.5$ (2EA)

+error : 0

- error : 2 (B_1, B_4)

(f) Classifier

(1) $x = -1.5$: $f_1(x) = \begin{cases} +1\ (+), & x_1 < -1.5 \\ -1\ (-) & \text{otherwise} \end{cases}$

$\varepsilon_1 = 2/11$, $\alpha_1 = \frac{1}{2}\ln\frac{9}{2} = 0.752$

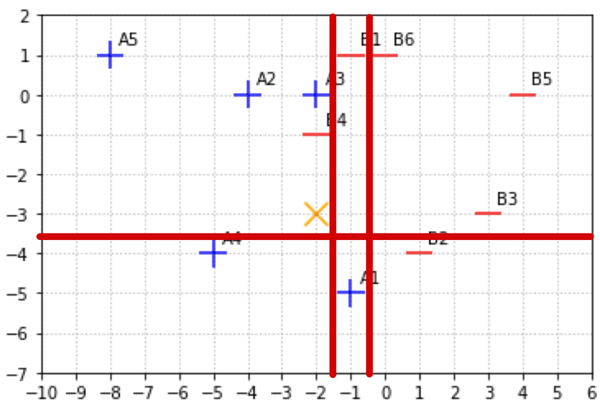
(2) $y = -3.5$: $f_2(x) = \begin{cases} +1\ (+), & x_2 < -3.5 \\ -1\ (-) & \text{otherwise} \end{cases}$

$\varepsilon_2 = 2/9$, $\alpha_2 = \frac{1}{2}\ln\frac{7}{2} = 0.626$

(3) $x = -0.5$: $f_3(x) = \begin{cases} +1\ (+), & x_3 < -0.5 \\ -1\ (-) & \text{otherwise} \end{cases}$

$\varepsilon_3 = \frac{11}{56}$, $\alpha_3 = \frac{1}{2}\ln\frac{45}{11} = 0.704$

$Y(x) = \text{sign}(\alpha_1 f_1(x) + \alpha_2 f_2(x) + \alpha_3 f_3(x))$



* New data X $(-2, -3)$

f_1 : $x = -2 < -1.5 \rightarrow +1$

f_2 : $y = -3 \geq -3.5 \rightarrow -1$

f_3 : $x = -2 < -0.5 \rightarrow +1$

$F(x) = \alpha_1 \cdot f_1 + \alpha_2 \cdot f_2 + \alpha_3 \cdot f_3$

$= 0.752 \cdot (+1) + 0.626 \cdot (-1) + 0.704 \cdot (+1)$

$= 0.83 \rightarrow$ + class

3. (24 points) [**Naïve Bayes + Decision Tree**] [**Graded by Tural Mehtiyev**] Consider the training data set below. Your goal is to build a classifier to predict *whether a patient should or should not be prescribed contact lenses.* The classifier will output 1 when it predicts that contact lenses should be prescribed and 0 when it predicts that they should not be prescribed. The output class is in the last column "Contact Lenses" and the input attributes are: "Patient Age", "Astigmatic", "Tear Production", and "Spectacle." More specifically, you will compare Naïve Bayes (NB) and Decision Tree (DT).

   For Naïve Bayes (NB), you will use *m-estimate* from the lecture with $m = 2$ and $p = 0.5$ for probability estimations.

   For Decision Tree (DT), you will follow the lecture's code to build your trees without pruning except that multiple-way splitting is allowed and use Information Gain (IG) to select the best attribute. In the case of ties, break ties in favor of the leftmost feature.

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?
0	Pre-presbyopic	False	Normal	Hypermetrope	No
1	Pre-presbyopic	False	Normal	Myope	No
2	Pre-presbyopic	True	Reduced	Myope	No
3	Young	True	Reduced	Myope	No
4	Young	True	Reduced	Hypermetrope	No
5	Pre-presbyopic	True	Reduced	Hypermetrope	No
6	Young	False	Reduced	Hypermetrope	No
7	Pre-presbyopic	True	Normal	Myope	No
8	Pre-presbyopic	False	Normal	Hypermetrope	No
9	Pre-presbyopic	True	Reduced	Myope	Yes
10	Pre-presbyopic	True	Reduced	Hypermetrope	Yes
11	Pre-presbyopic	False	Reduced	Myope	Yes
12	Pre-presbyopic	True	Normal	Myope	Yes
13	Young	True	Reduced	Hypermetrope	Yes

   (a) (18 points) Compare the performance of NB vs. DT using 2-fold cross-validation (CV) and **report their 2-fold CV accuracy**. **For the ith fold, the testing dataset is composed of all the data points whose (ID mod 2 $= i - 1$). For each fold, show the induced Naïve Bayes (in order of left to right columns) and DT models.**

   (b) (6 points) Based on the **2-fold CV accuracy** from (a), which classifier, NB or DT, would you choose? Report your final model for the selected classifier.

(a)

fold 1 : Train = {1, 3, 5, 7, 9, 11, 13}
Test = {0, 2, 4, 6, 8, 10, 12}
$P(y=0) = 4/7$, $P(y=1) = 3/7$

fold 2 : train = {0, 2, 4, 6, 8, 10, 12}
test = {1, 3, 5, 7, 9, 11, 13}

⟨Naïve Bayes⟩ Fold 1

⟨Naïve Bayes⟩ (m=2, p=0.5) Fold1

m-estimation : $P(A_i|C) = \dfrac{N_{ic} + mp}{N_c + m}$

* c : number of classes
p : prior probability
m : parameter

* Prior Probability

$P(y=0) = \dfrac{4 + 2\times0.5}{7+2} = \dfrac{5}{9}$

$P(y=1) = \dfrac{3 + 2\times0.5}{7+2} = \dfrac{4}{9}$

* Conditional Probability

$P(Age=P|y=0) = \dfrac{3+2\times0.5}{4+2} = \dfrac{4}{6} = \dfrac{2}{3}$

$P(Age=Y|y=0) = \dfrac{1+1}{4+2} = \dfrac{2}{6} = \dfrac{1}{3}$

$P(Age=P|y=1) = \dfrac{2+1}{3+2} = \dfrac{3}{5}$

$P(Age=Y|y=1) = \dfrac{1+1}{3+2} = \dfrac{2}{5}$

$P(Ast=F|y=0) = \dfrac{1+1}{4+2} = \dfrac{1}{3}$

$P(Ast=T|y=0) = \dfrac{3+1}{4+2} = \dfrac{2}{3}$

$P(Ast=F|y=1) = \dfrac{1+1}{3+2} = \dfrac{2}{5}$

$P(Ast=T|y=1) = \dfrac{2+1}{3+2} = \dfrac{3}{5}$

$P(Tear=N|y=0) = \dfrac{2+1}{4+2} = \dfrac{1}{2}$

$P(Tear=R|y=0) = \dfrac{2+1}{4+2} = \dfrac{1}{2}$

$P(Tear=N|y=1) = \dfrac{0+1}{3+2} = \dfrac{1}{5}$

$P(Tear=R|y=1) = \dfrac{3+1}{3+2} = \dfrac{4}{5}$

$P(Spec=H|y=0) = \dfrac{1+1}{4+2} = \dfrac{1}{3}$

$P(Spec=M|y=0) = \dfrac{3+1}{4+2} = \dfrac{2}{3}$

$P(Spec=H|y=1) = \dfrac{1+1}{3+2} = \dfrac{2}{5}$

$P(Spec=M|y=1) = \dfrac{2+1}{3+2} = \dfrac{3}{5}$

X | Y

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?
0	Pre-presbyopic	False	Normal	Hypermetrope	No
1	Pre-presbyopic	False	Normal	Myope	No
2	Pre-presbyopic	True	Reduced	Myope	No
3	Young	True	Reduced	Myope	No
4	Young	True	Reduced	Hypermetrope	No
5	Pre-presbyopic	True	Reduced	Hypermetrope	No
6	Young	False	Reduced	Hypermetrope	No
7	Pre-presbyopic	True	Normal	Myope	No
8	Pre-presbyopic	False	Normal	Hypermetrope	No
9	Pre-presbyopic	True	Reduced	Myope	Yes
10	Pre-presbyopic	True	Reduced	Hypermetrope	Yes
11	Pre-presbyopic	False	Reduced	Myope	Yes
12	Pre-presbyopic	True	Normal	Myope	Yes
13	Young	True	Reduced	Hypermetrope	Yes

No = 0
Yes = 1

ID 0 : P.F.N.H

$Score(y=0) = P(y=0)\prod_j P(x_j|y=0)$
$= \frac{5}{9}\cdot\frac{2}{3}\cdot\frac{1}{3}\cdot\frac{1}{2}\cdot\frac{1}{3} = \frac{5}{243} = 0.0206$

$Score(y=1) = P(y=1)\prod_j P(x_j|y=1)$
$= \frac{4}{9}\cdot\frac{3}{5}\cdot\frac{2}{5}\cdot\frac{1}{5}\cdot\frac{2}{5} = \frac{16}{1975} = 0.0085$

Score(0) > Score(1)
→ NO O

ID 2 : P.T.R.M

$Score(y=0) = \frac{5}{9}\times\frac{2}{3}\cdot\frac{2}{3}\cdot\frac{1}{2}\cdot\frac{2}{3} = \frac{5}{9}\times\frac{8}{54} = \frac{40}{486} = 0.0823$ ∨

$Score(y=1) = \frac{4}{9}\times\frac{3}{5}\cdot\frac{3}{5}\cdot\frac{4}{5}\cdot\frac{3}{5} = \frac{4}{9}\times\frac{108}{625} = \frac{432}{5625} = 0.0768$

→ No O

ID 4 : Y.T.R.H

$Score(y=0) = \frac{5}{9}\times\frac{1}{3}\cdot\frac{2}{3}\cdot\frac{1}{2}\cdot\frac{1}{3} = \frac{5}{9}\times\frac{2}{54} = \frac{10}{486} = 0.0206$ ∧

$Score(y=1) = \frac{4}{9}\times\frac{2}{5}\cdot\frac{3}{5}\cdot\frac{4}{5}\cdot\frac{2}{5} = \frac{4}{9}\times\frac{48}{625} = \frac{192}{5625} = 0.0341$

→ Yes X

ID 6 : Y.F.R.H

$Score(y=0) = \frac{5}{9}\times\frac{1}{3}\cdot\frac{1}{3}\cdot\frac{1}{2}\cdot\frac{1}{3} = \frac{5}{9}\times\frac{1}{54} = \frac{5}{486} = 0.0103$ ∧

$Score(y=1) = \frac{4}{9}\times\frac{2}{5}\cdot\frac{2}{5}\cdot\frac{4}{5}\cdot\frac{2}{5} = \frac{4}{9}\times\frac{32}{625} = \frac{128}{5625} = 0.0228$

→ Yes X

ID 8 : P.F.N.H

$Score(y=0) = \frac{5}{9}\times\frac{2}{3}\cdot\frac{1}{3}\cdot\frac{1}{2}\cdot\frac{1}{3} = \frac{5}{9}\times\frac{2}{54} = \frac{10}{486} = 0.0206$ ∨

$Score(y=1) = \frac{4}{9}\times\frac{3}{5}\cdot\frac{2}{5}\cdot\frac{1}{5}\cdot\frac{2}{5} = \frac{4}{9}\times\frac{12}{625} = \frac{48}{5625} = 0.0085$

→ No O

ID 10 : P.T.R.H

$Score(y=0) = \frac{5}{9}\times\frac{2}{3}\cdot\frac{2}{3}\cdot\frac{1}{2}\cdot\frac{1}{3} = \frac{5}{9}\times\frac{4}{54} = \frac{20}{486} = 0.0412$ ∧

$Score(y=1) = \frac{4}{9}\times\frac{3}{5}\cdot\frac{3}{5}\cdot\frac{4}{5}\cdot\frac{2}{5} = \frac{4}{9}\times\frac{72}{625} = \frac{288}{5625} = 0.0512$

→ Yes O

ID 12 : P.T.N.M

$Score(y=0) = \frac{5}{9}\times\frac{2}{3}\cdot\frac{2}{3}\cdot\frac{1}{2}\cdot\frac{2}{3} = \frac{5}{9}\times\frac{8}{54} = \frac{40}{486} = 0.082$ ∨

$Score(y=1) = \frac{4}{9}\times\frac{3}{5}\cdot\frac{3}{5}\cdot\frac{1}{5}\cdot\frac{3}{5} = \frac{4}{9}\times\frac{27}{625} = \frac{108}{5625} = 0.019$

→ No X

Predict Accuracy (fold1) = 4/7 = 0.57

fold2 : train = {0, 2, 4, 6, 8, 10, 12}
test = {1, 3, 5, 7, 9, 11, 13}
$P(y=0) = 5/7$, $P(y=1) = 2/7$

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?
0	Pre-presbyopic	False	Normal	Hypermetrope	No
1	Pre-presbyopic	False	Normal	Myope	No
2	Pre-presbyopic	True	Reduced	Myope	No
3	Young	True	Reduced	Myope	No
4	Young	True	Reduced	Hypermetrope	No
5	Pre-presbyopic	True	Reduced	Hypermetrope	No
6	Young	False	Reduced	Hypermetrope	No
7	Pre-presbyopic	True	Normal	Myope	No
8	Pre-presbyopic	False	Normal	Hypermetrope	No
9	Pre-presbyopic	True	Reduced	Myope	Yes
10	Pre-presbyopic	True	Reduced	Hypermetrope	Yes
11	Pre-presbyopic	False	Reduced	Myope	Yes
12	Pre-presbyopic	True	Normal	Myope	Yes
13	Young	True	Reduced	Hypermetrope	Yes

〈Naïve Bayes〉Fold 2

〈Naïve Bayes〉 (m=2, p=0.5) Fold2

* Prior Probability

$$P(y=0) = \frac{5+2\times0.5}{7+2} = \frac{6}{9} = \frac{2}{3}$$

$$P(y=1) = \frac{2+2\times0.5}{7+2} = \frac{3}{9} = \frac{1}{3}$$

* Conditional Probability

$$P(Age=P \mid y=0) = \frac{3+1}{5+2} = \frac{4}{7}$$

$$P(Age=Y \mid y=0) = \frac{2+1}{5+2} = \frac{3}{7}$$

$$P(Age=P \mid y=1) = \frac{0+1}{2+2} = \frac{1}{4}$$

$$P(Age=Y \mid y=1) = \frac{2+1}{2+2} = \frac{3}{4}$$

$$P(Ast=F \mid y=0) = \frac{3+1}{5+2} = \frac{4}{7}$$

$$P(Ast=T \mid y=0) = \frac{2+1}{5+2} = \frac{3}{7}$$

$$P(Ast=F \mid y=1) = \frac{0+1}{2+2} = \frac{1}{4}$$

$$P(Ast=T \mid y=1) = \frac{2+1}{2+2} = \frac{3}{4}$$

$$P(Tear=N \mid y=0) = \frac{2+1}{5+2} = \frac{3}{7}$$

$$P(Tear=R \mid y=0) = \frac{3+1}{5+2} = \frac{4}{7}$$

$$P(Tear=N \mid y=1) = \frac{1+1}{2+2} = \frac{2}{4}$$

$$P(Tear=R \mid y=1) = \frac{1+1}{2+2} = \frac{2}{4}$$

$$P(Spec=H \mid y=0) = \frac{4+1}{5+2} = \frac{5}{7}$$

$$P(Spec=M \mid y=0) = \frac{1+1}{5+2} = \frac{2}{7}$$

$$P(Spec=H \mid y=1) = \frac{1+1}{2+2} = \frac{2}{4}$$

$$P(Spec=M \mid y=1) = \frac{1+1}{2+2} = \frac{2}{4}$$

ID 1 : $Score(y=0) = \frac{2}{3}\cdot\frac{4}{7}\cdot\frac{4}{7}\cdot\frac{3}{7}\cdot\frac{2}{7} = \frac{192}{7203} = 0.267$
$\vee$
P·F·N·M
$Score(y=1) = \frac{1}{3}\cdot\frac{1}{4}\cdot\frac{1}{4}\cdot\frac{2}{4}\cdot\frac{2}{4} = \frac{4}{768} = 0.005$
→ No O

ID 3 : $Score(y=0) = \frac{2}{3}\cdot\frac{3}{7}\cdot\frac{3}{7}\cdot\frac{4}{7}\cdot\frac{2}{7} = \frac{144}{7203} = 0.02$
$\wedge$
Y·T·R·M
$Score(y=1) = \frac{1}{3}\cdot\frac{3}{4}\cdot\frac{3}{4}\cdot\frac{2}{4}\cdot\frac{2}{4} = \frac{36}{768} = 0.046$
→ Yes X

ID 5 : $Score(y=0) = \frac{2}{3}\cdot\frac{4}{7}\cdot\frac{3}{7}\cdot\frac{4}{7}\cdot\frac{5}{7} = \frac{480}{7203} = 0.067$
$\vee$
P·T·R·H
$Score(y=1) = \frac{1}{3}\cdot\frac{1}{4}\cdot\frac{3}{4}\cdot\frac{2}{4}\cdot\frac{2}{4} = \frac{12}{768} = 0.016$
→ No O

ID 7 : $Score(y=0) = \frac{2}{3}\cdot\frac{4}{7}\cdot\frac{3}{7}\cdot\frac{3}{7}\cdot\frac{2}{7} = \frac{144}{7203} = 0.02$
$\vee$
P·T·N·M
$Score(y=1) = \frac{1}{3}\cdot\frac{1}{4}\cdot\frac{3}{4}\cdot\frac{2}{4}\cdot\frac{2}{4} = \frac{12}{768} = 0.016$
→ No O

ID 9 : $Score(y=0) = \frac{2}{3}\cdot\frac{4}{7}\cdot\frac{3}{7}\cdot\frac{4}{7}\cdot\frac{2}{7} = \frac{192}{7203} = 0.027$
$\vee$
P·T·R·M
$Score(y=1) = \frac{1}{3}\cdot\frac{1}{4}\cdot\frac{3}{4}\cdot\frac{2}{4}\cdot\frac{2}{4} = \frac{12}{768} = 0.016$
→ No O

ID 11 : $Score(y=0) = \frac{2}{3}\cdot\frac{4}{7}\cdot\frac{4}{7}\cdot\frac{4}{7}\cdot\frac{2}{7} = \frac{256}{7203} = 0.036$
$\vee$
P·F·R·M
$Score(y=1) = \frac{1}{3}\cdot\frac{1}{4}\cdot\frac{1}{4}\cdot\frac{2}{4}\cdot\frac{2}{4} = \frac{4}{768} = 0.005$
→ No X

ID 13 : $Score(y=0) = \frac{2}{3}\cdot\frac{3}{7}\cdot\frac{3}{7}\cdot\frac{4}{7}\cdot\frac{5}{7} = \frac{360}{7203} = 0.05$
$\vee$
Y·T·R·H
→ No X
$Score(y=1) = \frac{1}{3}\cdot\frac{3}{4}\cdot\frac{3}{4}\cdot\frac{2}{4}\cdot\frac{2}{4} = \frac{36}{768} = 0.047$

Predict Accuracy (fold2) = 4/7 = 0.57

average NB Predict Accuracy (fold 1, fold 2)

= (0.57 + 0.57) / 2 = 0.57

⟨Decision Tree⟩ Fold 1

1. Calculate Entropy

1) Class Ratio

Yes = 3 → $P_Y = 3/7 = 0.429$

No = 4 → $P_N = 4/7 = 0.571$

$$H(L) = \sum_{i=1}^{k} -P_i \log_2 P_i$$

$$\xrightarrow{k=2(Yes/No)} = -\left(\frac{3}{7}\log_2\frac{3}{7} + \frac{4}{7}\log_2\frac{4}{7}\right)$$

$= 0.985$

$H(L|Yes) = 3$

① Patient Age

P: 5 (Yes = 2, No = 3) $H = -(\frac{2}{5}\log_2\frac{2}{5} + \frac{3}{5}\log_2\frac{3}{5}) = 0.971$

Y: 2 (Yes = 1, No = 1) $H = 1$

$H(L|Age) = \frac{5}{7}\times 0.971 + \frac{2}{7}\times 1 = 0.979$

② Astigmatic

F: 2 (Yes = 1, No = 1) $H = 1$

T: 5 (Yes = 2, No = 3) $H = 0.971$

$H(L|Ast) = \frac{2}{7}\times 1 + \frac{5}{7}\times 0.971 = 0.979$

③ Tear production

N: 2 (Yes = 0, No = 2) $H = 0$

R: 5 (Yes = 3, No = 2) $H = 0.971$

$H(L|Tear) = \frac{5}{7}\times 0.971 = 0.694$

④ Spectacle

Hy: 2 (Yes = 1, No = 1) $H = 1$

M: 5 (Yes = 2, No = 3) $H = 0.971$

$H(L|Spec) = 0.979$

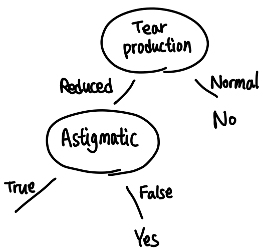
$H(L) = 0.985$

$H(L|Age) = 0.979$ $IG(L|Age) = 0.985 - 0.979 = 0.006$

$H(L|Ast) = 0.979$ $IG(L|Ast) = 0.985 - 0.979 = 0.006$

$H(L|Tear) = 0.694$ $IG(L|Tear) = 0.985 - 0.694 = 0.291$

$H(L|Spec) = 0.979$ $IG(L|Spec) = 0.985 - 0.979 = 0.006$



update

Training set

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?
[redacted]					
1	Pre-presbyopic	False	Normal	Myope	No
[redacted]					
3	Young	True	Reduced	Myope	No
[redacted]					
5	Pre-presbyopic	True	Reduced	Hypermetrope	No
[redacted]					
7	Pre-presbyopic	True	Normal	Myope	No
[redacted]					
9	Pre-presbyopic	True	Reduced	Myope	Yes
[redacted]					
11	Pre-presbyopic	False	Reduced	Myope	Yes
[redacted]					
13	Young	True	Reduced	Hypermetrope	Yes

Leaf : Reduced

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?
[redacted]					
3	Young	True	Reduced	Myope	No
[redacted]					
5	Pre-presbyopic	True	Reduced	Hypermetrope	No
[redacted]					
9	Pre-presbyopic	True	Reduced	Myope	Yes
[redacted]					
11	Pre-presbyopic	False	Reduced	Myope	Yes
[redacted]					
13	Young	True	Reduced	Hypermetrope	Yes

$H(L = Yes) = 3/5$

$H(L) = -(\frac{3}{5}\log_2\frac{3}{5} + \frac{2}{5}\log_2\frac{2}{5}) = 0.971$

① Patient Age

P: 3 (Yes = 2, No = 1) $H = -(\frac{2}{3}\log_2\frac{2}{3} + \frac{1}{3}\log_2\frac{1}{3}) = 0.918$

Y: 2 (Yes = 1, No = 1) $H = 1$

$H(L|Age) = \frac{3}{5}\times 0.918 + \frac{2}{5}\times 1 = 0.951$

② Astigmatic

T: 4 (Yes = 2, No = 2) $H = 1$

F: 1 (Yes = 1, No = 0) $H = 0$

$H(L|Ast) = \frac{4}{5}\times 1 = 0.8$

③ Spectacle

Hy: 2 (Yes = 1, No = 1) $H = 1$

M: 3 (Yes = 2, No = 1) $H = 0.918$

$H(L|Spec) = \frac{2}{5}\times 1 + \frac{3}{5}\times 0.918 = 0.951$

$H(L) = 0.971$

$H(L|Age) = 0.951$ $IG(L|Age) = 0.971 - 0.951 = 0.02$

$H(L|Ast) = 0.8$ $IG(L|Ast) = 0.971 - 0.8 = 0.171$

$H(L|Spec) = 0.951$ $IG(L|Spec) = 0.971 - 0.951 = 0.02$

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?
[redacted]					
3	Young	True	Reduced	Myope	No
[redacted]					
5	Pre-presbyopic	True	Reduced	Hypermetrope	No
[redacted]					
9	Pre-presbyopic	True	Reduced	Myope	Yes
[redacted]					
13	Young	True	Reduced	Hypermetrope	Yes

$H(L=Yes) = 2/4$ $\quad H(L) = 1$

① Patient Age

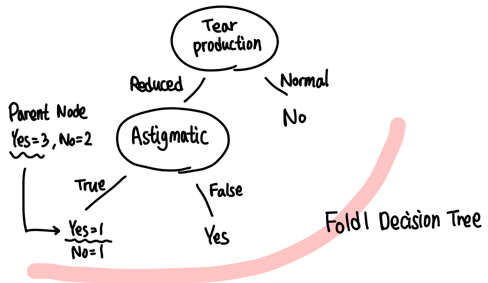
P : 2 (Yes=1, No=1) H=1 $\quad H(L|Age) = 1$

Y : 2 (Yes=1, No=1) H=1 $\quad IG(L|Age) = 0$

② Spectacle

Hy : 2 (Yes=1, No=1) H=1 $\quad H(L|Spec) = 1$

M : 2 (Yes=1, No=1) H=1 $\quad IG(L|Age) = 0$



2. Prediction

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?	
0	Pre-presbyopic	False	Normal	Hypermetrope	No	No O
[redacted]						
2	Pre-presbyopic	True	Reduced	Myope	No	Yes X
[redacted]						
4	Young	True	Reduced	Hypermetrope	No	Yes X
[redacted]						
6	Young	False	Reduced	Hypermetrope	No	Yes X
[redacted]						
8	Pre-presbyopic	False	Normal	Hypermetrope	No	No O
[redacted]						
10	Pre-presbyopic	True	Reduced	Hypermetrope	Yes	Yes O
[redacted]						
12	Pre-presbyopic	True	Normal	Myope	Yes	No X
[redacted]						

Accuracy = 3/7 = 0.429

<Decision Tree> Fold2

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?
0	Pre-presbyopic	False	Normal	Hypermetrope	No
[redacted]					
2	Pre-presbyopic	True	Reduced	Myope	No
[redacted]					
4	Young	True	Reduced	Hypermetrope	No
[redacted]					
6	Young	False	Reduced	Hypermetrope	No
[redacted]					
8	Pre-presbyopic	False	Normal	Hypermetrope	No
[redacted]					
10	Pre-presbyopic	True	Reduced	Hypermetrope	Yes
[redacted]					
12	Pre-presbyopic	True	Normal	Myope	Yes
[redacted]					

1. Calculate Entropy

1) Class Ratio

Yes = 2 $\rightarrow P_Y = 2/7 = 0.286$

No = 5 $\rightarrow P_N = 5/7 = 0.714$

$$H(L) = \sum_{i=1}^{k} -P_i \log_2 P_i$$

$$\xrightarrow{k=2(Yes/No)} = -\left(\frac{2}{7}\log_2\frac{2}{7} + \frac{5}{7}\log_2\frac{5}{7}\right)$$

$$= 0.863$$

$H(L|Yes) = 2/7$

① Patient Age

P : 5 (Yes=2, No=3) $H = -\left(\frac{2}{5}\log_2\frac{2}{5} + \frac{3}{5}\log_2\frac{3}{5}\right) = 0.971$

Y : 2 (Yes=0, No=2) H=0

$H(L|Age) = \frac{5}{7} \times 0.971 = 0.694$

② Astigmatic

F : 3 (Yes=0, No=3) H=0

T : 4 (Yes=2, No=2) H=1

$H(L|Ast) = \frac{4}{7} \times 1 = 0.571$

③ Tear production

N : 3 (Yes=1, No=2) $H = -\left(\frac{1}{3}\log_2\frac{1}{3} + \frac{2}{3}\log_2\frac{2}{3}\right) = 0.918$

R : 4 (Yes=1, No=3) $H = -\left(\frac{1}{4}\log_2\frac{1}{4} + \frac{3}{4}\log_2\frac{3}{4}\right) = 0.811$

$H(L|Tear) = \frac{3}{7} \times 0.918 + \frac{4}{7} \times 0.811 = 0.857$

④ Spectacle

Hy : 5 (Yes=1, No=4) $H = -\left(\frac{1}{5}\log_2\frac{1}{5} + \frac{4}{5}\log_2\frac{4}{5}\right) = 0.723$

M : 2 (Yes=1, No=1) H=1

$H(L|Spec) = \frac{5}{7} \times 0.723 + \frac{2}{7} \times 1 = 0.802$

H(L) = 0.863

H(L|Age) = 0.694 $\quad$ IG(L|Age) = 0.863 − 0.694 = 0.169

H(L|Ast) = 0.571 $\quad$ IG(L|Ast) = 0.863 − 0.571 = 0.292

H(L|Tear) = 0.857 $\quad$ IG(L|Tear) = 0.863 − 0.857 = 0.006

H(L|Spec) = 0.802 $\quad$ IG(L|Spec) = 0.863 − 0.802 = 0.061

Leaf: True

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?
[redacted]					
2	Pre-presbyopic	True	Reduced	Myope	No
[redacted]					
4	Young	True	Reduced	Hypermetrope	No
[redacted]					
10	Pre-presbyopic	True	Reduced	Hypermetrope	Yes
[redacted]					
12	Pre-presbyopic	True	Normal	Myope	Yes
[redacted]					

$H(L=\text{Yes}) = 2/4 \quad H(L)=1$

① Patient Age

P : 3 (Yes=2, No=1) H = 0.918

Y : 1 (Yes=0, No=1) H = 0

$H(L|\text{Age}) = \frac{3}{4} \times 0.918 = 0.689$

② Tear production

N : 1 (Yes=1, No=0) H=0

R : 3 (Yes=1, No=2) H = 0.918

$H(L|\text{Tear}) = \frac{3}{4} \times 0.918 = 0.689$

③ Spectacle

Hy : 2 (Yes=1, No=1) H=1

M : 2 (Yes=1, No=1) H=1

$H(L|\text{Spec}) = 1$

H(L) = 1

$H(L|\text{Age}) = 0.689 \quad IG(L|\text{Age}) = 1-0.689 = 0.311$

$H(L|\text{Tear}) = 0.689 \quad IG(L|\text{Tear}) = 1-0.689 = 0.311$

$H(L|\text{Spec}) = 1 \quad IG(L|\text{Spec}) = 0$

Leaf: Pre-presbyopic

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?
[redacted]					
2	Pre-presbyopic	True	Reduced	Myope	No
[redacted]					
10	Pre-presbyopic	True	Reduced	Hypermetrope	Yes
[redacted]					
12	Pre-presbyopic	True	Normal	Myope	Yes
[redacted]					

$H(L=\text{Yes}) = 2/3 \quad H(L) = 0.918$

① Tear production

N : 1 (Yes=1, No=0) H=0

R : 2 (Yes=1, No=1) H=1

$H(L|\text{Tear}) = \frac{2}{3} \times 1 = 0.667$

$IG(L|\text{Tear}) = 0.918 - 0.667 = 0.251$

② Spectacle

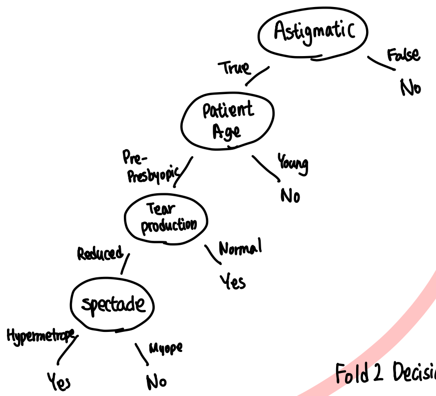
Hy : 1 (Yes=1, No=0) H=0

M : 2 (Yes=1, No=1) H=1

$H(L|\text{Spec}) = \frac{2}{3} \times 1 = 0.667$

$IG(L|\text{Spec}) = 0.918 - 0.667 = 0.251$

update



Fold 2 Decision Tree

2. Prediction

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?	
[redacted]						
1	Pre-presbyopic	False	Normal	Myope	No	No o
[redacted]						
3	Young	True	Reduced	Myope	No	No o
[redacted]						
5	Pre-presbyopic	True	Reduced	Hypermetrope	No	Yes x
[redacted]						
7	Pre-presbyopic	True	Normal	Myope	No	Yes x
[redacted]						
9	Pre-presbyopic	True	Reduced	Myope	Yes	No x
[redacted]						
11	Pre-presbyopic	False	Reduced	Myope	Yes	No x
[redacted]						
13	Young	True	Reduced	Hypermetrope	Yes	No x

Accuracy = 2/7 = 0.286

Average DT predict Accuracy

= (0.429 + 0.286) / 2 = 0.357

%	Fold 1	Fold 2	Average
NB	57.1	57.1	57.1
DT	42.9	28.6	35.7

(b) NB Acc (57.1%) > DT Acc (35.7%)

ID	Patient Age	Astigmatic	Tear Production	Spectacle	Contact Lenses?
0	Pre-presbyopic	False	Normal	Hypermetrope	No
1	Pre-presbyopic	False	Normal	Myope	No
2	Pre-presbyopic	True	Reduced	Myope	No
3	Young	True	Reduced	Myope	No
4	Young	True	Reduced	Hypermetrope	No
5	Pre-presbyopic	True	Reduced	Hypermetrope	No
6	Young	False	Reduced	Hypermetrope	No
7	Pre-presbyopic	True	Normal	Myope	No
8	Pre-presbyopic	False	Normal	Hypermetrope	No
9	Pre-presbyopic	True	Reduced	Myope	Yes
10	Pre-presbyopic	True	Reduced	Hypermetrope	Yes
11	Pre-presbyopic	False	Reduced	Myope	Yes
12	Pre-presbyopic	True	Normal	Myope	Yes
13	Young	True	Reduced	Hypermetrope	Yes

$Y \in \{1(\text{Yes}), 0(\text{No})\}$

1) prior probability ($m=2$, $p=0.5$)

$N=14$ Yes $=5$, No $=9$

$P(Y=\text{Yes}) = \frac{N_Y + mp}{N+m} = \frac{5+1}{14+2} = \frac{6}{16} = 0.375$

$P(Y=\text{No}) = \frac{9+1}{14+2} = \frac{10}{16} = 0.625$

2) Conditional Probability

① Patient Age

$P(\text{Age}=P \mid Y=\text{Yes}) = \frac{4+1}{5+2} = \frac{5}{7}$

$P(\text{Age}=Y \mid Y=\text{Yes}) = \frac{1+1}{5+2} = \frac{2}{7}$

$P(\text{Age}=P \mid Y=\text{No}) = \frac{6+1}{9+2} = \frac{7}{11}$

$P(\text{Age}=Y \mid Y=\text{No}) = \frac{3+1}{9+2} = \frac{4}{11}$

② Astigmatic

$P(\text{Ast}=F \mid Y=\text{Yes}) = \frac{1+1}{5+2} = \frac{2}{7}$

$P(\text{Ast}=T \mid Y=\text{Yes}) = \frac{4+1}{5+2} = \frac{5}{7}$

$P(\text{Ast}=F \mid Y=\text{No}) = \frac{4+1}{9+2} = \frac{5}{11}$

$P(\text{Ast}=T \mid Y=\text{No}) = \frac{5+1}{9+2} = \frac{6}{11}$

③ Tear Production

$P(\text{Tear}=N \mid Y=\text{Yes}) = \frac{1+1}{5+2} = \frac{2}{7}$

$P(\text{Tear}=R \mid Y=\text{Yes}) = \frac{4+1}{5+2} = \frac{5}{7}$

$P(\text{Tear}=N \mid Y=\text{No}) = \frac{4+1}{9+2} = \frac{5}{11}$

$P(\text{Tear}=R \mid Y=\text{No}) = \frac{5+1}{9+2} = \frac{6}{11}$

④ Spectacle

$P(\text{Spec}=H \mid Y=\text{Yes}) = \frac{2+1}{5+2} = \frac{3}{7}$

$P(\text{Spec}=M \mid Y=\text{Yes}) = \frac{3+1}{5+2} = \frac{4}{7}$

$P(\text{Spec}=H \mid Y=\text{No}) = \frac{5+1}{9+2} = \frac{6}{11}$

$P(\text{Spec}=M \mid Y=\text{No}) = \frac{4+1}{9+2} = \frac{5}{11}$

predict rule example

ID 0 → P·F·N·H ← attribute

$\text{Score}(y=1:\text{Yes}) = \frac{6}{16} \cdot \frac{5}{7} \cdot \frac{2}{7} \cdot \frac{2}{7} \cdot \frac{3}{7} = \frac{360}{38416} = 0.00937$

$\text{Score}(y=0:\text{No}) = \frac{10}{16} \cdot \frac{7}{11} \cdot \frac{5}{11} \cdot \frac{5}{11} \cdot \frac{6}{11} = \frac{10500}{234256} = 0.04482$

class

score(1) < score(0) ⇒ No