

## CS 534 Homework Assignment 3 (100 Points)

**Due: 11:59 p.m. on 06/26/2022**

**Homework Objective:** The goal of this assignment is to help you master the materials of Lecture 4 and 5.

**Homework Deliverables:** Submit your answers and solutions in a *zip* file that includes all the write-ups in a *pdf* file and your *python codes* to Canvas.

### Notes:

1. Each answer needs to be explained.
2. The implementation should be in Python if You need.

### **Project Questions:**

**Question 1.** Consider the problem of deciding whether a propositional logic (*PL*) sentence is true in a given model. Write a recursive algorithm *PL-True?(s, m)* that returns true if and only if the sentence *s* is true in the model *m* (where *m* assigns a truth value for every symbol in *s*). The algorithm should run in *time linear* in the size of the sentence. The original algorithm can be found in the function *pl\_true()* in *logic4e.py*.

If you have forgotten the concept of recursive algorithms that you have learned in your prerequisites, you can review this website (<https://realpython.com/python-recursion/>) to refresh your memory.

**Question 2.** Consider a first-order logical knowledge base that describes worlds containing people, songs, albums (e.g., “Meet the Beatles”) and disks (i.e., particular physical instances of CDs). The vocabulary contains the following symbols:

> *CopyOf(d, a)*: Predicate. Disk *d* is a copy of album *a*. > *Owns(p, d)*: Predicate. Person *p* owns disk *d*. > *Sings(p, s, a)*: Album *a* includes a recording of song *s* sung by person *p*. > *Wrote(p, s)*: Person *p* wrote song *s*. > *McCartney, Gershwin, BHoliday, Joe, EleanorRigby, TheManILove, Revolver*: Constants with the obvious meanings.

Express the following statements in first-order logic:

- a. Gershwin wrote “The Man I Love.”
- b. Gershwin did not write “Eleanor Rigby.”
- c. Either Gershwin or McCartney wrote “The Man I Love.”
- d. Joe has written at least one song.
- e. Joe owns a copy of \*Revolver\*.
- f. Every song that McCartney sings on \*Revolver\* was written by McCartney.
- g. Gershwin did not write any of the songs on \*Revolver\*.
- h. Every song that Gershwin wrote has been recorded on some album. (Possibly different songs are recorded on different albums.)
- i. There is a single album that contains every song that Joe has written.
- j. Joe owns a copy of an album that has Billie Holiday singing “The Man I Love.”
- k. Joe owns a copy of every album that has a song sung by McCartney. (Of course, each different album is instantiated in a different physical CD.)
- l. Joe owns a copy of every album on which all the songs are sung by Billie Holiday.

**Question 3.** Consider the following dataset ( $x_1, x_2, \dots, x_5$ ) comprised of three binary input attributes ( $A_1, A_2$ , and  $A_3$ ) and one binary output:

Example	$A_1$	$A_2$	$A_3$	Output $y$
$x_1$	1	0	0	0
$x_2$	1	0	1	0
$x_3$	0	1	0	0
$x_4$	1	1	1	1
$x_5$	1	1	0	1

- Use the Gini Index to learn a decision tree for these data. Show the computations made to determine the attribute to split at each node. Draw the final tree.
- Use the Information Gain to learn a decision tree for these data. Show the computations made to determine the attribute to split at each node. Draw the final tree.

**Question 4.** Consider the following set of examples ( $A_1, A_2, \dots, A_{14}$ ), each with six inputs ( $x_1, x_2, \dots, x_6$ ) and one target output  $T$ :

Example	$A_1$	$A_2$	$A_3$	$A_4$	$A_5$	$A_6$	$A_7$	$A_8$	$A_9$	$A_{10}$	$A_{11}$	$A_{12}$	$A_{13}$	$A_{14}$
$x_1$	1	1	1	1	1	1	1	0	0	0	0	0	0	0
$x_2$	0	0	0	1	1	0	0	1	1	0	1	0	1	1
$x_3$	1	1	1	0	1	0	0	1	1	0	0	0	1	1
$x_4$	0	1	0	0	1	0	0	1	0	1	1	1	0	1
$x_5$	0	0	1	1	0	1	1	0	1	1	0	0	1	0
$x_6$	0	0	0	1	0	1	0	1	1	0	1	1	1	0
$T$	1	1	1	1	1	1	0	1	0	0	0	0	0	0

- Run the perceptron learning rule on these data, show the final equation, and draw the final perceptron architecture. Include your Python code in the submission.
  - Reference: [https://scikit-learn.org/stable/modules/generated/sklearn.linear\\_model.Perceptron.html](https://scikit-learn.org/stable/modules/generated/sklearn.linear_model.Perceptron.html)
- Run the decision tree learning rule on these data ( $x_1, x_2, \dots, x_6$ ), and show the resulting decision tree. Include your Python code in the submission.
  - Reference: <https://scikit-learn.org/stable/modules/tree.html#classification>
- Comment on your prediction results by using both algorithms if there is an unseen  $A_{15}$ :  $\langle 1, 1, 0, 0, 1, 1 \rangle$ . The true  $T$  of  $A_{15}$  is 1. Include your Python code in the submission.

**Grading Criteria:** Your answers must be complete and clear.