Washington State University
School of Electrical Engineering and Computer Science
Fall 2018

CptS 440/540 Artificial Intelligence
Homework 11 Solution
Due: November 29, 2018 (11:59pm)

General Instructions: Put your answers to the following problems into a PDF document and submit as an attachment under Content → Homework 11 for the course CptS 440 Pullman (all sections of CptS 440 and 540 are merged under the CptS 440 Pullman section) on the Blackboard Learn system by the above deadline. Note that you may submit multiple times, but we will only grade the most recent entry submitted before the above deadline.

For this homework we will be applying two different learning methods to the following 10 examples (same as in HW10). Each example describes weather conditions in terms of the features: Sky ∈ {clear, cloudy, overcast}, Sea ∈ {blue, gray}, and Sun ∈ {true, false}. The class Sail ∈ {yes, no} indicates whether or not we should go sailing in these conditions.

Sky	**Sea**	**Sun**	**Sail**
clear	blue	false	yes
clear	gray	true	yes
clear	gray	false	no
cloudy	blue	true	yes
cloudy	blue	false	yes
cloudy	gray	true	yes
cloudy	gray	false	no
overcast	blue	true	yes
overcast	blue	false	yes
overcast	gray	false	no

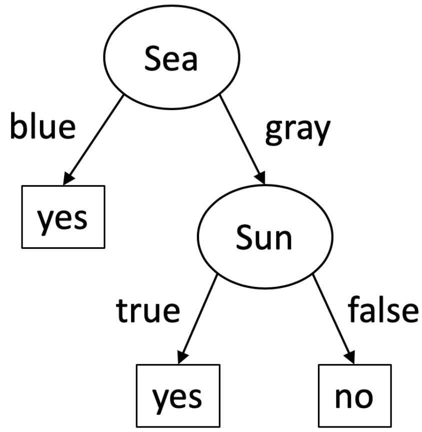
1. *Decision Tree*. Compute the following for learning a decision tree from the examples above. Show your work.
   a. Compute the entropy of the training set, consisting of the above 10 examples.
   b. Compute the information gain for using Sky as the test at the root of the decision tree.
   c. Compute the information gain for using Sea as the test at the root of the decision tree.
   d. Compute the information gain for using Sun as the test at the root of the decision tree.
   e. Show the final decision tree learned by the DECISION-TREE-LEARNING algorithm in Figure 18.5 of the textbook.
   f. How would the learned Decision Tree classify the new instance <Sky=overcast, Sea=gray, Sun=true>?

   Solution:
   a. Entropy(7,3) = – (7/10) lg (7/10) – (3/10) lg (3/10) = 0.881
   b. Gain(Sky) = Entropy(7,3) – [(3/10) Entropy(2,1) + (4/10) Entropy(3,1) + (3/10) Entropy(2,1)]
   = 0.881 – [(0.3)(0.918) + (0.4)(0.811) + (0.3)(0.918)] = 0.0058

c. Gain(Sea) = Entropy(7,3) – [(5/10) Entropy(5,0) + (5/10) Entropy(2,3)]
= 0.881 – [(0.5)(0.0) + (0.5)(0.971)] = 0.396

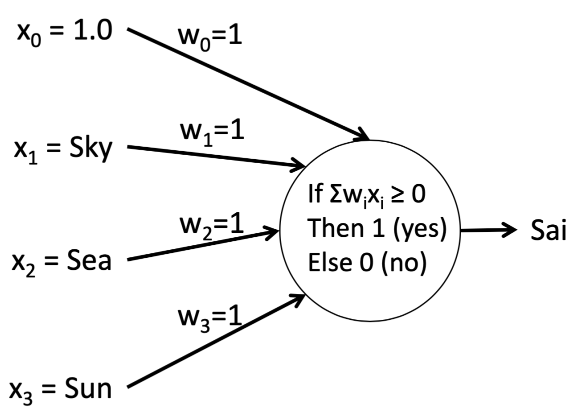
d. Gain(Sun) = Entropy(7,3) – [(4/10) Entropy(4,0) + (6/10) Entropy(3,3)]
= 0.881 – [(0.4)(0.0) + (0.6)(1.0)] = 0.281

e. Since Sea has highest gain, the final decision tree has Sea at the root. For Sea=blue, all examples are Sail=yes. For Sea=gray, there are two Sail=yes and three Sail=no examples. For these five examples, the Sun attribute leads to pure nodes, but the Sky attribute does not. So, Sun's gain will be greater than Sky's for these five examples. Thus, the final decision tree is:



f. The decision tree would classify the instance <Sky=overcast, Sea=gray, Sun=true> as <u>Yes</u>.

2. *Perceptron*. Train a perceptron on the 10 examples in the above table and then use the perceptron to classify the new instance. Specifically,
   a. Translate the examples (including the Sail class value) according to the mapping: clear → 1, cloudy → 2, overcast → 3, blue → 1, gray → 2, false → 1, true → 2, no→ 0, yes → 1. Show a new table of examples using this mapping. *Note: this mapping is different than the one used in HW10.*
   b. Train the perceptron below by updating the weights according to the perceptron learning rule (equation 18.7 in the textbook). Assume the initial weights are all equal to 1.0, and α = 0.5. Consider each example in the order presented in the table above and show the weight updates for each incorrectly-classified example. Continue until the perceptron correctly classifies all the training examples, and show the final perceptron weights. *Hint*: The perceptron should correctly classify all 10 examples on the 3rd pass through the examples.
   c. How would the learned perceptron classify the new instance <Sky=overcast, Sea=gray, Sun=true>? Show your work.



Solution:

a. Table below.

Sky	Sea	Sun	Sail
1	1	1	1
1	2	2	1
1	2	1	0
2	1	2	1
2	1	1	1
2	2	2	1
2	2	1	0
3	1	2	1
3	1	1	1
3	2	1	0

b. Below are the weight updates for each pass through the 10 examples.

Pass #1
Example 1 correct
Example 2 correct
Example 3 incorrect, new weights: w0=0.5 w1=0.5 w2=0 w3=0.5
Example 4 correct
Example 5 correct
Example 6 correct
Example 7 incorrect, new weights: w0=0 w1=-0.5 w2=-1 w3=0
Example 8 incorrect, new weights: w0=0.5 w1=1 w2=-0.5 w3=1
Example 9 correct
Example 10 incorrect, new weights: w0=0 w1=-0.5 w2=-1.5 w3=0.5

Pass #2
Example 1 incorrect, new weights: w0=0.5 w1=0 w2=-1 w3=1
Examples 2-10 correct

Pass #3
Examples 1-10 correct

Final Weights:
w0=0.5 w1=0 w2=-1 w3=1

c. The new instance would map to <Sky=3, Sea=2, Sun=2>. Multiplying the weights times the inputs: $(0.5)(1) + (0)(3) + (-1)(2) + (1)(2) = 0.5 \geq 0$. Thus, the output is 1 or <u>Yes</u>.

3. (*CptS 540 Students Only*). Put the 10 training examples from the initial table above (used in Problem 1) into an ARFF file suitable for input to WEKA. Follow the procedure below to produce a decision tree that correctly classifies all 10 examples.
    a. Download and install WEKA from www.cs.waikato.ac.nz/ml/weka/downloading.html.
    b. Start WEKA and choose the Explorer mode.
    c. Under the Preprocess tab, choose "Open file..." and load your ARFF file.
    d. Under the Classify tab, choose the "trees→J48" classifier. This is WEKA's decision tree learning method. The default parameters should be sufficient for this problem.
    e. Under Test options, choose "Use training set".
    f. Click Start to run the classifier on your data. J48 should learn a decision tree that achieves 100% accuracy on the training examples.
    g. Include your ARFF file and WEKA's output in your PDF submission.

Solution:

ARFF File:

```
@relation sail

@attribute sky {clear, cloudy, overcast}
@attribute sea {blue, gray}
@attribute sun {true, false}
@attribute sail {yes, no}

@data
clear,blue,false,yes
clear,gray,true,yes
clear,gray,false,no
cloudy,blue,true,yes
cloudy,blue,false,yes
cloudy,gray,true,yes
cloudy,gray,false,no
overcast,blue,true,yes
overcast,blue,false,yes
overcast,gray,false,no
```

WEKA Output:

```
=== Run information ===

Scheme:       weka.classifiers.trees.J48 -C 0.25 -M 2
Relation:     sail
Instances:    10
Attributes:   4
              sky
              sea
              sun
              sail
Test mode:    evaluate on training data

=== Classifier model (full training set) ===

J48 pruned tree
------------------

sea = blue: yes (5.0)
sea = gray
|   sun = true: yes (2.0)
|   sun = false: no (3.0)

Number of Leaves  :   3

Size of the tree :    5


Time taken to build model: 0.01 seconds

=== Evaluation on training set ===

Time taken to test model on training data: 0 seconds

=== Summary ===

Correctly Classified Instances          10              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Relative absolute error                  0      %
Root relative squared error              0      %
Coverage of cases (0.95 level)         100      %
Mean rel. region size (0.95 level)      50      %
Total Number of Instances               10

=== Detailed Accuracy By Class ===

                 TP Rate  FP Rate  Precision  Recall   F-Measure  MCC      ROC Area  PRC Area  Class
                 1.000    0.000    1.000      1.000    1.000      1.000    1.000     1.000     yes
                 1.000    0.000    1.000      1.000    1.000      1.000    1.000     1.000     no
Weighted Avg.    1.000    0.000    1.000      1.000    1.000      1.000    1.000     1.000

=== Confusion Matrix ===

 a b   <-- classified as
 7 0 | a = yes
 0 3 | b = no
```