Washington State University
School of Electrical Engineering and Computer Science
Fall 2019

CptS 440/540 Artificial Intelligence
Homework 10 – Solution
Due: November 14, 2019 (11:59pm)

General Instructions: Put your answers to the following problems into a PDF document and submit as an attachment under Content → Homework 10 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 11 examples. Each example describes the Weather ∈ {clear, cloudy, rain}, whether or not your AI homework is done (AIDone ∈ {yes, no}), and whether or not you have a costume (Costume ∈ {yes, no}). The class HaveFun ∈ {yes, no} indicates whether or not you will have fun at a party under these conditions.

Weather	AIDone	Costume	HaveFun
clear	yes	yes	yes
clear	yes	no	yes
clear	no	yes	yes
clear	no	no	no
cloudy	yes	yes	yes
cloudy	no	yes	no
cloudy	no	no	no
rain	yes	yes	yes
rain	yes	no	yes
rain	no	yes	no
rain	no	no	no

1. *Naïve Bayes*. Suppose we want to classify the new instance <Weather=cloudy, AIDone=yes, Costume=no> using the naïve Bayes learning method. Compute the following. Show your work. Note: only use the "add 1 / |values|" technique if the original P(attribute | class) = 0.
    a. Compute the prior probabilities P(HaveFun=yes) and P(HaveFun=no).
    b. Compute P(Weather | HaveFun) for all values of Weather ∈ {clear, cloudy, rain} and HaveFun ∈ {yes, no}.
    c. Compute P(AIDone | HaveFun) for all values of AIDone ∈ {yes, no} and HaveFun ∈ {yes, no}.
    d. Compute P(Costume | HaveFun) for all values of Costume ∈ {yes, no} and HaveFun ∈ {yes, no}.
    e. Compute P(HaveFun=yes | Weather=cloudy, AIDone=yes, Costume=no) and P(HaveFun=no | Weather=cloudy, AIDone=yes, Costume=no).
    f. Which class would Naïve Bayes choose for the new instance?

Solution:

a. P(HaveFun=yes) = 6/11 = 0.545
   P(HaveFun=no) = 5/11 = 0.455

b. P(Weather=clear | HaveFun=yes) = 3/6 = 0.5
   P(Weather=cloudy | HaveFun=yes) = 1/6 = 0.167
   P(Weather=rain | HaveFun=yes) = 2/6 = 0.333
   P(Weather=clear | HaveFun=no) = 1/5 = 0.2
   P(Weather=cloudy | HaveFun=no) = 2/5 = 0.4
   P(Weather=rain | HaveFun=no) = 2/5 = 0.4

c. P(AIDone=yes | HaveFun=yes) = 5/6 = 0.833
   P(AIDone=no | HaveFun=yes) = 1/6 = 0.167
   P(AIDone=yes | HaveFun=no) = 0/5 = 0
      Since values(AIDone)=2, recompute as (0+1)/(5+2) = 1/7 = 0.143
   P(AIDone=no | HaveFun=no) = 5/5 = 1

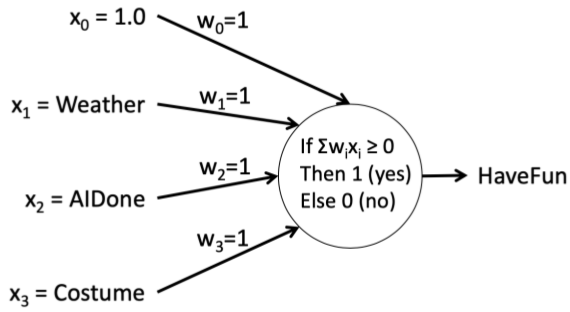
d. P(Costume=yes | HaveFun=yes) = 4/6 = 0.667
   P(Costume=no | HaveFun=yes) = 2/6 = 0.333
   P(Costume=yes | HaveFun=no) = 2/5 = 0.4
   P(Costume=no | HaveFun=no) = 3/5 = 0.6

e. P(HaveFun=yes | Weather=cloudy, AIDone=yes, Costume=no)
   = α * P(Weather=cloudy, AIDone=yes, Costume=no | HaveFun=yes) * P(HaveFun=yes)
   = α * P(Weather=cloudy | HaveFun=yes) * P(AIDone=yes | HaveFun=yes) *
      P(Costume=no | HaveFun=yes) * P(HaveFun=yes)
   = α * (1/6) * (5/6) * (2/6) * (6/11)
   = α * 0.025 = <u>0.61</u>
   P(HaveFun=no | Weather=cloudy, AIDone=yes, Costume=no)
   = α * P(Weather=cloudy, AIDone=yes, Costume=no | HaveFun=no) * P(HaveFun=no)
   = α * P(Weather=cloudy | HaveFun=no) * P(AIDone=yes | HaveFun=no) *
      P(Costume=no | HaveFun=no) * P(HaveFun=no)
   = α * (2/5) * (1/7) * (3/5) * (5/11)
   = α * 0.016 = <u>0.39</u>
   α = 1 / (0.025 + 0.016) = 24.39

f. Since P(HaveFun=yes | Weather=cloudy, AIDone=yes, Costume=no) > P(HaveFun=no | Weather=cloudy, AIDone=yes, Costume=no), Naive Bayes would classify this instance as "<u>yes</u>".

2. *Perceptron*. Train a perceptron on the 11 examples in the above table and then use the perceptron to classify the new instance. Specifically,
   a. First, translate the examples (including the HaveFun class value) according to the mapping: clear → 1, cloudy → 2, rain → 3, no→ 0, yes → 1. Show a new table of examples using this mapping.
   b. Train the perceptron below by updating the weights according to the perceptron learning rule (slide 35 of Learning lecture). Assume the initial weights are all equal to 1.0, and η = 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 11 examples on the 3rd pass through the examples.

c. How would the learned perceptron classify the new instance <Weather=cloudy, AIDone=yes, Costume=no>? Show your work.



Solution:

a. Table.

Weather	AIDone	Costume	HaveFun
1	1	1	1
1	1	0	1
1	0	1	1
1	0	0	0
2	1	1	1
2	0	1	0
2	0	0	0
3	1	1	1
3	1	0	1
3	0	1	0
3	0	0	0

b. Three passes.

```
Pass #1
  Example 1 correct
  Example 2 correct
  Example 3 correct
  Example 4 incorrect, new weights: w0=0.5 w1=0.5 w2=1 w3=1
  Example 5 correct
  Example 6 incorrect, new weights: w0=0 w1=-0.5 w2=1 w3=0.5
  Example 7 correct
  Example 8 correct
  Example 9 incorrect, new weights: w0=0.5 w1=1 w2=1.5 w3=0.5
  Example 10 incorrect, new weights: w0=0 w1=-0.5 w2=1.5 w3=0
  Example 11 correct
Pass #2
  Example 1 correct
  Example 2 correct
  Example 3 incorrect, new weights: w0=0.5 w1=0 w2=1.5 w3=0.5
  Example 4 incorrect, new weights: w0=0 w1=-0.5 w2=1.5 w3=0.5
  Example 5 correct
  Example 6 correct
  Example 7 correct
  Example 8 correct
  Example 9 correct
  Example 10 correct
  Example 11 correct
Pass #3
  Example 1 correct
  Example 2 correct
  Example 3 correct
  Example 4 correct
  Example 5 correct
  Example 6 correct
  Example 7 correct
  Example 8 correct
  Example 9 correct
  Example 10 correct
  Example 11 correct
Final Weights:
 w0=0 w1=-0.5 w2=1.5 w3=0.5
```

c. New instance to be classified is <2,1,0>. The network output would be
$(0)(1) + (-0.5)(2) + (1.5)(1) + (0.5)(0) = 0.5$
Since output ≥ 0, the predicted class is "yes".

3. *CptS 540 Students Only*: Put the 11 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 run the Naive Bayes classifier.
    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 "bayes→NaiveBayes" classifier.
    e. Under Test options, choose "Use training set".
    f. Click Start to run the classifier on your data.
    g. Include your ARFF file and WEKA's output in your submission.

Solution:

ARFF File:

```
@relation havefun

@attribute weather {clear, cloudy, rain}
@attribute aidone {yes, no}
@attribute costume {yes, no}
@attribute havefun {yes, no}


@data
clear,yes,yes,yes
clear,yes,no,yes
clear,no,yes,yes
clear,no,no,no
cloudy,yes,yes,yes
cloudy,no,yes,no
cloudy,no,no,no
rain,yes,yes,yes
rain,yes,no,yes
rain,no,yes,no
rain,no,no,no
```

WEKA Output:

```
=== Run information ===

Scheme:       weka.classifiers.bayes.NaiveBayes
Relation:     havefun
Instances:    11
Attributes:   4
              weather
              aidone
              costume
              havefun
Test mode:    evaluate on training data

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

Naive Bayes Classifier

                Class
Attribute         yes     no
               (0.54) (0.46)
=============================
weather
  clear            4.0    2.0
  cloudy           2.0    3.0
  rain             3.0    3.0
  [total]          9.0    8.0

aidone
  yes              6.0    1.0
  no               2.0    6.0
  [total]          8.0    7.0

costume
  yes              5.0    3.0
  no               3.0    4.0
  [total]          8.0    7.0

Time taken to build model: 0 seconds

=== Evaluation on training set ===

Time taken to test model on training data: 0 seconds

=== Summary ===

Correctly Classified Instances          10               90.9091 %
Incorrectly Classified Instances         1                9.0909 %
Kappa statistic                          0.8197
Mean absolute error                      0.2093
Root mean squared error                  0.2438
Relative absolute error                 42.1626 %
Root relative squared error             48.9498 %
Total Number of Instances               11

=== Detailed Accuracy By Class ===

                 TP Rate  FP Rate  Precision  Recall   F-Measure  MCC      ROC Area  PRC Area  Class
                 0.833    0.000    1.000      0.833    0.909      0.833    1.000     1.000     yes
                 1.000    0.167    0.833      1.000    0.909      0.833    1.000     1.000     no
Weighted Avg.    0.909    0.076    0.924      0.909    0.909      0.833    1.000     1.000

=== Confusion Matrix ===

 a b   <-- classified as
 5 1 | a = yes
 0 5 | b = no
```