In my class announcement I made a mistake: I did not mean to say that you may work in groups on this exam. I meant that for the project, but somehow I made that error. So, you MAY NOT WORK IN GORUPS FOR THE EXAM.

**This page is to be turned in as part of your exam. PLEASE DO NOT FORGET TO PRINT YOUR NAME ON EACH PAGE OF THE EXAM.**

**STUDENTS ARE ALLOWED/ENCOURAGED TO:**

* **Consult any resources they want/need, including online resources.**
  + **Any resource (other than notes and textbook) used to answer the problems in this exam must be indicated in the exam, as citations and listed as reference at the end of the exam (references should appear in alphabetical order of the last name of the author, and numbered accordingly; citations should appear as numbers between brackets such as [3]).**
* **Contact the instructor if they need any clarification of the statements of the exam.**

**STUDENTS ARE NOT ALLOWED TO**:

* **Discuss the content of the exam with anybody (including family members, friends, class mates, or other instructors) until AFTER the DEADLINE to turn in the exam even if they have turned it in before the deadline.**

**Please be aware that I will watch for identical or unusually similar solutions on different exams!!!!**

**Before starting the exam.** Please read the statement below, electronically sign it by typing your initials and fill in the date you did so.

*“I promise that I will follow the rules set forth above for working on this exam”*

**Initials: \_OTA\_\_ Date: \_\_\_10/22/15\_\_\_\_\_**

**After finishing the exam, before the solutions you turned in**. Please read the statement below and electronically sign it by typing your initials and fill in the date you did so.

*“I give my word of honor that* ***I have followed the rules set forth above*** *for working on this exam, that the solution I am turning in is mine, and mine alone.”*

**Initials: \_OTA\_ Date: \_\_\_10/22/15\_\_**

TOBI: Answers are available in the answers folder, code source available in the source folder

**Problem 1 (On conditional probabilities).**

In the following ~B denotes the negation or complement.  
**(a) (3 points)** Assume that **P(A|B)**  is given.  Can we compute **P(B|A)**?  Explain your answer.   
**(b) (4 points)** Assume **P(A|B) = 3/4** and **P(A | ~B) = 1/4**.  Can we compute **P(B|A)**.  If yes, compute it, if not, explain why not.   
**(c) (4 points)** Assume **P(A|B) = 3/4, P(A|~B)= 1/4** and **P(B) = 1/4**.  Can we compute **P(B| A)**?  If yes, compute it if not explain why not.   
**(d) (4 points)** Assume **P(A|B) = 3/4, P(A|~B)= 1/4** and **P(B) =1/4, P(A) = 3/8**.  Can we compute **P(B| A)**?  If yes, compute it if not explain why not.

**Problem 2**. Consider the class of concepts C of the form (a x b) ^ (c y d) where a, b, c, d {0, 1, 2}.

**(a)** **(3 points)** How many **distinct concepts** C can be formed?

**(b) (3 points)** What happens if we allow a, b to take also negative integer values, that is, a, b {−2,−1, 0, 1, 2} while c and d remain with values in {0, 1, 2}? How many distinct concepts as described above are there in this case?

**(c) (3 points)** Consider now the subclass of concepts, C1 in C of the same form but with additional constraint that (b − a) (d − c). How many concepts are in C1?

**(d) (3 points)** Let H = C, H1 = C1 denote two hypotheses spaces. Assume that H is used in conjunction with C1. **Can we talk about consistent learners in this framework**? Explain. (Recall that a consistent learner refers to a learning algorithm that outputs a consistent hypothesis, that is, a hypothesis that makes zero errors over the training set).

**(e) (3 points)** Answer the previous question when H1 is used in conjunction with C.

**Problem 3. (10 points)** Give the decision tree representing the following Boolean formula (A, B, C, D take values **T**(true) or **F**(false)).

**(A OR B) AND (C OR ~D)**

**Problem 4.** Consider the following data set in which points in the 2D space are classified as **+** or **-** :

|  |  |  |
| --- | --- | --- |
| x1 | x2 | Class |
| 0 | 0 | + |
| 2 | 2 | - |
| 2.5 | 2.5 | - |
| 0 | 2 | + |
| 1 | 2 | - |
| 2 | 0 | + |

1. **(3 points)** Plot these points, label each point with a ‘+’ or ‘-‘. Are these classes linearly separable?
2. **(5 points)** Train a perceptron such that each point is correctly classified by it, and plot the decision surface w0 + w1x1+w2x2 = 0.
3. **(7 points)** Repeat training (three times) by alternatively removing one of the negative points (positive class remains unchanged). For each training, record the decision surface obtained and compare its coefficients to those of the decision surface in part (b). Which one is closer to it? Give an intuitive interpretation of your answer.

**Problem 5.** In each of the following training examples, A1, A2, and A3 are binary attributes, taking the values T(true) or F(false).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Instance | A1 | A2 | A3 | Class |
| 1 | T | T | T | + |
| 2 | T | F | T | + |
| 3 | T | F | F | - |
| 4 | F | F | T | + |
| 5 | F | T | F | - |
| 6 | F | T | T | - |

**(a)** **(3 points)** What is the entropy, **H**, of this collection of examples with respect to the classification?

**(b)** **(3 points)** What is **H(A3|A2 = T)**?

**(c) (3 points)** Draw the full decision tree output by the ID3 algorithm (with no pruning) for this data.

**(d) (3 points)** Is there any error when the tree obtained in part (c) above is used on this data set? Explain your answer.

**(e)(3 points)** How will the data points be classified by the decision tree obtained in part (c)?

|  |  |  |  |
| --- | --- | --- | --- |
| A1 | A2 | A3 | Class |
| T | T | F | ? |
| F | F | F | ? |

**Problem 6. (Bayesian Learning)** **(15 points)** Recall the table of examples to train the concept **PlayTennis**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Example** | **Outlook** | **Temp.** | **Humidity** | **Wind** | **PlayTennis** |
| 1 | Sunny | Hot | High | Weak | - |
| 2 | Sunny | Hot | High | Strong | - |
| 3 | Overcast | Hot | High | Weak | + |
| 4 | Rain | Mild | High | Weak | + |
| 5 | Rain | Cool | Normal | Weak | + |
| 6 | Rain | Cool | Normal | Strong | - |
| 7 | Overcast | Cool | Normal | Strong | + |
| 8 | Sunny | Mild | High | Weak | - |
| 9 | Sunny | Cool | Normal | Weak | + |
| 10 | Rain | Mild | Normal | Weak | + |
| 11 | Sunny | Mild | Normal | Strong | + |
| 12 | Overcast | Mild | High | Strong | + |
| 13 | Overcast | Hot | Normal | Weak | + |
| 14 | Rain | Mild | High | Strong | - |

Use the Naïve Bayes classifier to classify the instance: **(**Outlook **= Sunny,** Temp = **Cool,** Humidity = **Normal,** Wind = **Weak)**

**Problem 7.** For the same data as in Problem 6 (same table).

1. **(6 points)** Show the hypothesis obtained by applying ***Find\_S*** on all the examples in the table. Then use this hypothesis to classify the instance **(**Outlook **= Sunny,** Temp = **Cool,** Humidity = **Normal,** Wind = **Weak)**
2. **(9 points)** Show the hypothesis obtained by applying ***Candidate\_Elimination*** on all the examples in the table. Then use this hypothesis to classify the instance **(**Outlook **= Sunny,** Temp = **Cool,** Humidity = **Normal,** Wind = **Weak)**