Istanbul Technical University
BLG527E Machine Learning
Homework 5

Purpose: Getting ready for the final exam.

Total worth: 6% of your grade.

Handed out: Tuesday, January 2, 2018.

Due: Wednesday, January 10, 2018 **10:00** (**morning**!). (through ninova!)

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Policy: Collaboration in the form of discussions is acceptable, but you should write your own answer/code by yourself. Cheating is highly discouraged for it could mean a zero or negative grade from the homework.

If a question is not clear, please let us know (via email, during office hour or in class).

Submission Instructions: Please submit through the class ninova site.
Please upload all your files using filename studentID_HW5.docx or .pdf.
Use a **black**/blue pen (please not a pencil) to write down your homework or a word processor (latex/word/pages etc.). You can scan or take photos of your homework. Provide only one answer on each page of your submission.
If you have not submitted a question, submit a blank page with the question name on it.

Copy and paste the table below and put it at the first page of your submission. Mark the assessment of your grade (0 or 1) for each question.

STUDENT NAME: **STUDENT ID:**

STUDENT ASSESSMENT OF HW20

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20

1. (Ch13)Given 10 training data points (X) and the predefined kernel between them (K) as follows and labels r_i=1 if i<=5 and r_i=-1 otherwise. Train a SVM classifier with given kernel and find all alpha values belonging to classifier. Use these alphas to classify the datapoint x=[0.3, 0.2]

$$X = \begin{matrix} 1.6715 & 2.0347 \\ -0.2075 & 1.7269 \\ 1.7172 & 0.6966 \\ 2.6302 & 1.2939 \\ 1.4889 & 0.2127 \\ -0.1116 & 0.4384 \\ -2.1471 & -0.6748 \\ -2.0689 & -1.7549 \\ -1.8095 & 0.3703 \\ -3.9443 & -2.7115 \end{matrix}$$

K =

1.00	0.22	0.36	0.41	0.23	0.15	0.04	0.03	0.06	0.02
0.22	1.00	0.17	0.11	0.16	0.37	0.10	0.06	0.19	0.03
0.36	0.17	1.00	0.46	0.78	0.23	0.06	0.05	0.07	0.02
0.41	0.11	0.46	1.00	0.29	0.11	0.04	0.03	0.05	0.02
0.23	0.16	0.78	0.29	1.00	0.28	0.07	0.06	0.08	0.03
0.15	0.37	0.23	0.11	0.28	1.00	0.16	0.10	0.26	0.04
0.04	0.10	0.06	0.04	0.07	0.16	1.00	0.46	0.45	0.12
0.03	0.06	0.05	0.03	0.06	0.10	0.46	1.00	0.18	0.18
0.06	0.19	0.07	0.05	0.08	0.26	0.45	0.18	1.00	0.07
0.02	0.03	0.02	0.02	0.03	0.04	0.12	0.18	0.07	1.00

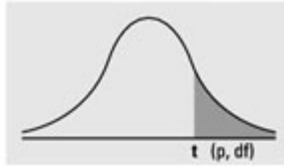
2. (Ch16) Assume that you have a chain of random variables X1 -> X2 -> X3-> X4, with P(X1) = 0.2 and P(Xi|Xi-1) = 0.8. Compute P(X3|X1,~X4) using belief propagation.

3. (Ch19) Assume that you have used MLP, KNN and (NB) Naive Bayes as classification methods and 10 fold cross validation. The errors for each fold and classifiers are given below.

   a) With significance level alpha=0.05, would you accept that error of MLP is equal to error of KNN?
   b) (Read Ch19 first) Use ANOVA to show whether error_MLP = error_KNN = error_NB or not at alpha=0.05 significance level.

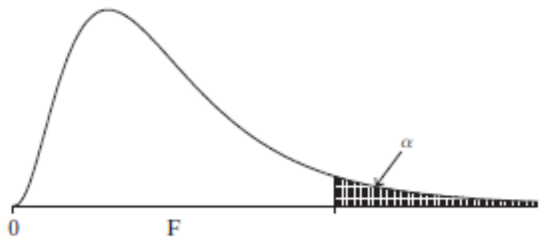
MLP	KNN	NB
0.00	0.00	0.07
0.00	0.07	0.07
0.00	0.00	0.00
0.07	0.07	0.07
0.13	0.13	0.07
0.00	0.00	0.07
0.13	0.07	0.13
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00

Numbers in each row of the table are values on a *t*-distribution with (*df*) degrees of freedom for selected right-tail (greater-than) probabilities (*p*).



df/p	0.40	0.25	0.10	0.05	0.025	0.01	0.005	0.0005
1	0.324920	1.000000	3.077684	6.313752	12.70620	31.82052	63.65674	636.6192
2	0.288675	0.816497	1.885618	2.919986	4.30265	6.96456	9.92484	31.5991
3	0.276671	0.764892	1.637744	2.353363	3.18245	4.54070	5.84091	12.9240
4	0.270722	0.740697	1.533206	2.131847	2.77645	3.74695	4.60409	8.6103
5	0.267181	0.726687	1.475884	2.015048	2.57058	3.36493	4.03214	6.8688
6	0.264835	0.717558	1.439756	1.943180	2.44691	3.14267	3.70743	5.9588
7	0.263167	0.711142	1.414924	1.894579	2.36462	2.99795	3.49948	5.4079
8	0.261921	0.706387	1.396815	1.859548	2.30600	2.89646	3.35539	5.0413
9	0.260955	0.702722	1.383029	1.833113	2.26216	2.82144	3.24984	4.7809
10	0.260185	0.699812	1.372184	1.812461	2.22814	2.76377	3.16927	4.5869
11	0.259556	0.697445	1.363430	1.795885	2.20099	2.71808	3.10581	4.4370
12	0.259033	0.695483	1.356217	1.782288	2.17881	2.68100	3.05454	43178
13	0.258591	0.693829	1.350171	1.770933	2.16037	2.65031	3.01228	4.2208
14	0.258213	0.692417	1.345030	1.761310	2.14479	2.62449	2.97684	4.1405
15	0.257885	0.691197	1.340606	1.753050	2.13145	2.60248	2.94671	4.0728
16	0.257599	0.690132	1.336757	1.745884	2.11991	2.58349	2.92078	4.0150
17	0.257347	0.689195	1.333379	1.739607	2.10982	2.56693	2.89823	3.9651
18	0.257123	0.688364	1.330391	1.734064	2.10092	2.55238	2.87844	3.9216
19	0.256923	0.687621	1.327728	1.729133	2.09302	2.53948	2.86093	3.8834
20	0.256743	0.686954	1.325341	1.724718	2.08596	2.52798	2.84534	3.8495
21	0.256580	0.686352	1.323188	1.720743	2.07961	2.51765	2.83136	3.8193
22	0.256432	0.685805	1.321237	1.717144	2.07387	2.50832	2.81876	3.7921
23	0.256297	0.685306	1.319460	1.713872	2.06866	2.49987	2.80734	3.7676
24	0.256173	0.684850	1.317836	1.710882	2.06390	2.49216	2.79694	3.7454
25	0.256060	0.684430	1.316345	1.708141	2.05954	2.48511	2.78744	3.7251
26	0.255955	0.684043	1.314972	1.705618	2.05553	2.47863	2.77871	3.7066
27	0.255858	0.683685	1.313703	1.703288	2.05183	2.47266	2.77068	3.6896
28	0.255768	0.683353	1.312527	1.701131	2.04841	2.46714	2.76326	3.6739
29	0.255684	0.683044	1.311434	1.699127	2.04523	2.46202	2.75639	3.6594
30	0.255605	0.682756	1.310415	1.697261	2.04227	2.45726	2.75000	3.6460
z	0.253347	0.674490	1.281552	1.644854	1.95996	2.32635	2.57583	3.2905
CI	———	———	80%	90%	95%	98%	99%	99.9%

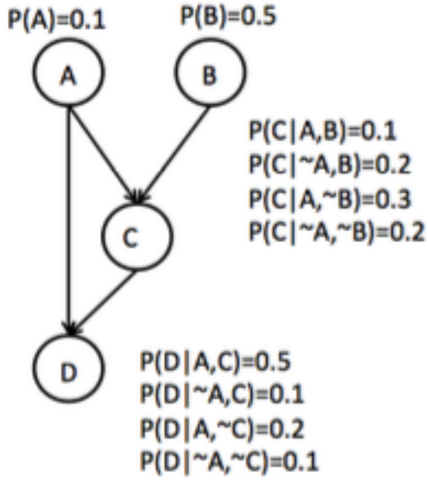
TABLE D: *F* **Distribution**



$\alpha = .05$										
	df_1									
df_2	1	2	3	4	5	6	8	12	24	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	238.9	243.9	249.0	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.37	19.41	19.45	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.84	8.74	8.64	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.04	5.91	5.77	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.82	4.68	4.53	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.15	4.00	3.84	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.73	3.57	3.41	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.44	3.28	3.12	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.23	3.07	2.90	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.07	2.91	2.74	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	2.95	2.79	2.61	2.40
12	4.75	3.88	3.49	3.26	3.11	3.00	2.85	2.69	2.50	2.30
13	4.67	3.80	3.41	3.18	3.02	2.92	2.77	2.60	2.42	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.70	2.53	2.35	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.64	2.48	2.29	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.59	2.42	2.24	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.55	2.38	2.19	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.51	2.34	2.15	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.48	2.31	2.11	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.45	2.28	2.08	1.84
21	4.32	3.47	3.07	2.84	2.68	2.57	2.42	2.25	2.05	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.40	2.23	2.03	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.38	2.20	2.00	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.36	2.18	1.98	1.73
25	4.24	3.38	2.99	2.76	2.60	2.49	2.34	2.16	1.96	1.71
26	4.22	3.37	2.98	2.74	2.59	2.47	2.32	2.15	1.95	1.69
27	4.21	3.35	2.96	2.73	2.57	2.46	2.30	2.13	1.93	1.67
28	4.20	3.34	2.95	2.71	2.56	2.44	2.29	2.12	1.91	1.65
29	4.18	3.33	2.93	2.70	2.54	2.43	2.28	2.10	1.90	1.64
30	4.17	3.32	2.92	2.69	2.53	2.42	2.27	2.09	1.89	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.18	2.00	1.79	1.51
60	4.00	3.15	2.76	2.52	2.37	2.25	2.10	1.92	1.70	1.39
120	3.92	3.07	2.68	2.45	2.29	2.17	2.02	1.83	1.61	1.25
∞	3.84	2.99	2.60	2.37	2.21	2.09	1.94	1.75	1.52	1.00

Source: From Table V of R. A. Fisher and F. Yates, *Statistical Tables for Biological, Agricultural and Medical Research*, published by Longman Group Ltd., London, 1974. (Previously published by Oliver & Boyd, Edinburgh.) Reprinted by permission of the authors and publishers.

4. (Ch16) For the Bayesian network shown below, compute *P(D|B):*



5. (Ch19) (Read Ch19 first) Schizophrenia is a mental disorder where the patients confuse what is real and what is their imagination. It highly reduces the quality of life for both the patients and for people close to them. It is known that 1 in every 100 individual has schizophrenia. Recently scientists came up with a genetic signature that only 7 percent of schizophrenic people don't have it. And only 9 percent of healthy individuals have the signature. There is a gene therapy when the fetus is not more than 5 months old but it has risks of course. Even when the fetus will really have schizophrenia the cost of the procedure is decided to be 10 units. But if the fetus will not be schizophrenic the cost of the therapy is 60 units. If we do not apply the therapy and the fetus will have schizophrenia the cost is assumed to be 100 units. Suppose you are faced with a fetus that shows the genetic signature for schizophrenia, would you apply the therapy? Justify your decision.

6. (Ch14) Given that p(x) ~ N(mu, sigma2), constant and known sigma2, prior distribution for mu as p(mu) ~ N(0,1), and N observations X = {x1,...,xN}

derive the posterior distribution for x: p(x|X)

7. (Ch4) Assume you observed one coin tossed 11 times and the observations at time ***t=1*** to ***t=11*** are as follows: **{H,T,H,H,H,T,T,T,H,T,T}**. Is the outcome at toss ***t+1*** independent of the outcome at toss ***t***? Why or why not?

8. (Ch6)

8a) Name two differences between PCA (Principal Component Analysis) and Backward Feature Selection.

8b) Name two differences between mRMR (minimum Redundancy Maximum Relevance) Feature Selection and Forward Feature Selection.

8c) Name two differences between PCA and LDA (Linear Discriminant Analysis).

9. (Ch7) Consider the four unlabeled data points **{x1 = (1,1), x2 = (2,1), x3 = (2.5,0.5), x4 = (2,0)}**

   a) Show these data points on 2 dimensional plane. You need to divide these datapoints into 2 clusters. What would be the most reasonable clustering? Give the coordinates of the center of each cluster. (Use **city block distance** as the distance measure: **|a,b|=|a1-b1|+|a2-b2|**)

   b) Considering all possible initial cluster centers (assume that 2 different cluster centers are chosen randomly among the four data points), what are the clusterings produced by the k-means clustering algorithm with k=2.

   c) Use hierarchical clustering with average-link distance (distance between centroids) to cluster these data points

10. (Ch7) What is EM (Expectation Maximization) Algorithm? Give details of how it is used to compute the mixture probabilities, means and covariance matrices for GMMs (Gaussian Mixture Models).

11. (Ch8) a) Given a classification problem with inputs X = {x1,...,xN} with outputs r={r1,...,rN} write down the Parzen window estimator for the output for a given input x. How would your estimator change for density estimation or regression?

12. (Ch9) a) Given a classification problem and a dataset with continuous outputs, you want to train a decision tree. For each node, instead of splitting on one variable at a time, you want to split using multivariate logistic regression classifiers. Give details of how you would train such a decision tree. b) You want to use a decision tree for regression. How would you train such a decision tree if you are allowed to use multivariate regression at each node?

13. (Ch10) Given a function of the form g(w1,w2,x) = w1*x*x + w1*w2*x + w2*x + w1 and squared error, derive the partial derivative of the error function with respect to both parameters w1 and w2 and explain how you would use gradient descent to determine the best values of w1 and w2 for a particular dataset with inputs X = {x1,...,xN} with outputs r={r1,...,rN}

14. (Ch13) Compare the error functions used by SVM and MLP for classification (regularized error vs error) and regression (hinge loss vs squared error). Explain why these error functions could help SVM generalize better.

15. (Ch11)

a) Explain how each of the following help for the training of a MLP: adaptive learning rate, momentum, L2 regularization.

b) How do you initialize a MLP and why?

c) Write down and compare the error functions and MLP architectures that you would use to train a MLP for a regression problem and for a classification problem.

16. (Ch11)

a) Assume that you have a regression problem with one dimensional inputs and you know the following hint about your problem: if ($x<5$) the output should increase with x and if $x>=5$ the output should decrease with x. You are given a training data set X of N labeled instances also. Explain how could you train a MLP taking into account both the hint and the dataset X.

b) Assume that you have received a training dataset X1 and trained an MLP using that dataset. Let the resulting MLP be MLP1. A while later you received another dataset X2. You do not have access to dataset X1 anymore but you have MLP1. Explain how could you train an MLP so that you could learn both X1 and X2 at the same time.

17. (Ch18) a) Give two differences between Bagging and Adaboost. b) Assume that you combined K classifiers using stacking with a MLP with as many layers as you need. Prove that the Adaboost combiner can be implemented with MLP-stacking. c) Under what conditions (of, for example, problem difficulty, number of instances, number of features, number of base classifiers) could you prefer Adaboost over MLP-stacking?

18. (Ch4)

a) Suppose you are given a financial regression dataset generated from **a polynomial of degree of 4**. Indicate whether you think the bias and variance of the following models would be relatively high (H) or low (L) considering the true model.

i) Polynomial of degree 1,

ii) Polynomial of degree 4,

iii) Polynomial of degree 10

iv) Polynomial of degree 10 trained with regularization

b) How do you compute bias and variance when you are only given a limited training set?

c) Given a multivariate binary classification problem and assumption of normally distributed d dimensional inputs, what are the most complex and least complex classifiers that you could produce? Explain in detail your assumptions to arrive at those classifiers and the number of parameters needed to be estimated from training data.

19. (Deep Learning) a) What are the differences between a deep neural network and multilayer perceptron? What is a CNN (Convolutional Neural Network)? What is dropout?

20. (Ch15)

a) What is the difference between a First Order Markov Model and a Second Order Markov Model?

b) What are the differences between a Markov Model and a Hidden Markov Model (HMM)?

c) What are the parameters λ of a HMM?

d) Given a sequence of observations O = {o1,o2,…,oT}, how do you compute P(O| λ) (i.e. the probability that O was produced by the HMM with parameter λ)?

e) Which algorithm do you use to find the most probable state sequence given a sequence of observations O? How does that algorithm work?

f) Which algorithm do you use to compute the parameters of an HMM given a set of K observation sequences each of of length T? How does that algorithm work?