南方科技大学
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Course Name： Machine Learning (H) **Exam Duration：** 2 hours

Dept.： Department of Computer Science and Engineering

Exam Paper Setter(Signature)： QiHao

Question No.	1	2	3	4	5	6	7	8	9	10
Score	20	50	30	10						

This exam paper contains 4 questions and the score is 110 in total. (Please hand in your exam paper, answer sheet, and your scrap paper to the proctor when the exam ends.)

Problem I Multiple Choice (20 Points)

(*only one correct answer for each question*)

1. **(2 points)** The most essential component of an unsupervised learning system is _____.

A. cost function
B. learning model
C. latent variable
D. optimization algorithm

2. **(2 points)** The objective of machine learning is to minimize _____.

A. the KL divergence between real-world data and the trained probabilistic model
B. the KL divergence between training data and the trained probabilistic model
C. the KL divergence between real-world data and training data
D. the KL divergence between training data and prediction data

3. **(2 points)** What is the loss function most suited for logistic regression?

A. the mutual information function
B. the squared error function
C. the cross-entropy function
D. the hinge error function

4. **(2 points)** What is the loss function most suited for probabilistic density mixture model based clustering?

A. the cross-entropy function of complete data
B. the cross-entropy function of incomplete data

C. the expected likelihood function of complete data

D. the expected likelihood function of incomplete data

5. **(2 points)** The major differences between the maximum likelihood and maximum a posterior approaches include _____.

A. that the former uses more model parameters

B. that the former has high computation complexity

C. that the latter emphasizes the prior upon model parameters

D. that the latter has lower convergence speeds

6. **(2 points)** Neural networks can NOT be regularized by using _____.

A. model parameter priors

B. data augmentation

C. node dropping out

D. ReLU activation

7. **(2 points)** The advantages of the hidden Markov model DO NOT include _____.

A. guaranteed global convergence

B. fast estimation algorithm

C. capability of prediction of the future data sequence

D. capability of modeling both continuous and discrete data

8. **(2 points)** The difference between the expected likelihood function of incomplete data and complete data for unsupervised learning is _____.

A. the KL-divergence between the distributions of latent variables

B. the KL-divergence between the training data and the learning model

C. the entropy of the distribution of latent variables

D. the entropy of the complete-data function

9. **(2 points)** Which of the following is NOT a way to reduce the model overfitting?

A. adding training tasks for the learning model

B. adding priors upon the learning model parameters

C. increase the learning model complexity

D. increase the training data complexity

10. **(2 points)** Which of the following statements is NOT true for Markov decision process?

A. it can be used to solve non-stationary problems.

B. it can be solved by using either policy iteration or value iteration approaches.

C. solving the Bellman equation requires state transition and reward models.

D. its fixed point is the optimal policy.

Problem II Numerical Calculation (50 Points)

(1) **Linear Regression (5 points)**. For three points {(1, 3), (2, 7), (3, 13)}, what is the linear regression function for the least squared errors (*assuming* $y = a_2x^2 + a_1x + a_0$) and what are the predictive outputs for the inputs of 0 and 4?

(2) **Supervised Classification (5 points)**. For class A of two points {(1, 2) (2, 1)} and class B of two points {(4, 1) (3, 4)}, what are the labels for points {(2,2) (3,3)} using the K-NN algorithm (*where K*=3)?

(3) **Maximum Margin Classifier (10 points)**. For one class of two points {(0, 1) (1, 1)} and another class of two points {(2, 2) (2, 3)}, what are the decision boundary's function and the cost function for the soft margin case (*plot your answer*) ?

(4) **Clustering (10 points)**. For four points with two classes, {(0, 1) (1, 1) (2, 2) (2, 3)}, how to achieve two cluster centers using the K-means algorithm (*outline the algorithm and show the details of one iteration*)?

(5) **Hidden Markov Model (10 points)**. For a HMM, the states of latent variables are {bull, bear}, the states of observation variables are {rise, fall}, the initial state probability distribution $\boldsymbol{\pi}$ is $[0.5\ 0.5]^T$, the transition probability distribution $\boldsymbol{A}$ is [0.6 0.3; 0.4 0.7], and the observation probability distribution $\boldsymbol{B}$ is [0.8 0.1;0.2 0.9]. If the observation sequence $\boldsymbol{X}$ is {rise fall fall}, please show the computation procedure for $p(z_2|\boldsymbol{X}, \boldsymbol{\theta})$ and $p(z_2, z_3|\boldsymbol{X}, \boldsymbol{\theta})$ using the forward-backward algorithm, where z_n is the latent variable at time n and $\boldsymbol{\theta} = \{\boldsymbol{\pi}, \boldsymbol{A}, \boldsymbol{B}\}$?

(6) **Neural Network (10 points)**. For an XOR logic function, how to design a neural network to achieve the similar function (*provide the main idea, the NN model structure, and show the details of one iteration*)?

Problem III Theoretical Analysis (30 Points)

For a finite-state random sequence $\{Z_t\}$with the model of $\{\pi, A\}$ and its observation sequence is $\{X_t\}$, the joint distribution of X and Z with the model θ is given by

$$p(X, Z|\theta) = \prod_{i=1}^{K} [p(z_i)p(X|\theta_i)]^{z_i}$$

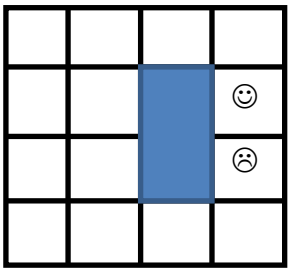
(1) Summarize the general forward-backward EM scheme for HMM (***E***-step and ***M***-step).

(2) Assuming each observation probability density is Bernoulli, *i.e.* $p(X|\theta_i) = \theta_i^x(1-\theta_i)^{1-x}$, please derive the corresponding model learning procedure under the EM scheme.

(3) Use the prior upon $\theta = \{\pi, A, \theta_i\}$ to derive the MAP-EM learning algorithms.

(4) Please provide a discussion on the advantages of using the MAP-EM scheme for sequential data learning.

Problem IV Markov Decision Process (Bonus 10 Points)



Given the robot motion planning problem as shown in the right, which contains *robot positions*, *obstacles*, right and wrong *goals*. Assume that the robot can only move one step a time in four directions: {up, down, right, left}.

(1) Please set up the reward and the state transition functions.

(2) Please derive the optimal value functions using the value iteration approach (*using two states as example*).

(3) Please derive the optimal policy using the policy iteration approaches (*showing the policy evaluation and improvement procedures in figures*).

(4) Please provide a discussion upon the advantages and disadvantages of using value iteration and policy iteration methods, respectively?