UNIVERSITY OF TORONTO

Faculty of Arts and Science

April 2016 Final Examination

CSC411H1S

Duration - 2 hours

No Aids Allowed

Please check that your exam has 10 pages, including this one.

Use the back of the page if you need more space on a question.

Point Distribution

Problem 1:	25
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Name:

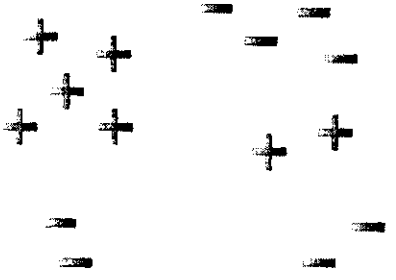
Student Number:

1. Ensemble Methods [25 points].

   - (5 pts) What is the key underlying idea that may allow an ensemble method to achieve lower error rate than a single model?

   - (5 pts) How does the Adaboost algorithm work?

   - (5 pts) Assume that decision stumps are used as the simple classifiers in Adaboost. What kind of a decision boundary does the ensemble classifier have in this case? Draw the decision boundary in the example below.



- (5 pts) Explain the idea behind the mixture-of-experts model. What is the key difference with respect to boosting?

- (5 pts) How do you train a random forrest? How do you perform classification with a random forrest?

2. Mixture Models [25 points].

   - (10pts) How does the soft K-means algorithm work? Explain it in detail. What is the main difference with K-means?

   - (10 pts) Consider a simple form of mixture model, in which each mixture component is a spherical Gaussian density of dimension d:

$$p(\mathbf{x}|\{\theta_k\}) = \sum_{k=1}^{K} P(z = k|\theta) p(\mathbf{x}|z = k, \theta_k)$$

$$p(\mathbf{x}|z = k, \theta_k) = \frac{1}{(2\pi\sigma_k^2)^{d/2}} \exp\left(-\frac{|\mathbf{x} - \mu_\mathbf{k}|^2}{2\sigma_k^2}\right)$$

   where $\theta_k = (\pi_k, \mu_k, \sigma_k)$. What does the random variable z represent? How many parameters are in this model? How does EM estimate them?

- (5 pts) You have labeled training data, where each training example $\mathbf{x}_i$ belongs to one out of C classes. Assume that for each class $p(\mathbf{x}|y = c)$ is a mixture model with the form in the exercise above. Further assume that you also know the prior distribution $p(y)$. How would you classify a new example $\mathbf{x}$?

3. Unsupervised Learning [20 points].

- (5 pts) What is the idea behind PCA? Pick one of the objective functions of PCA, write it down, and explain what is it trying to do.

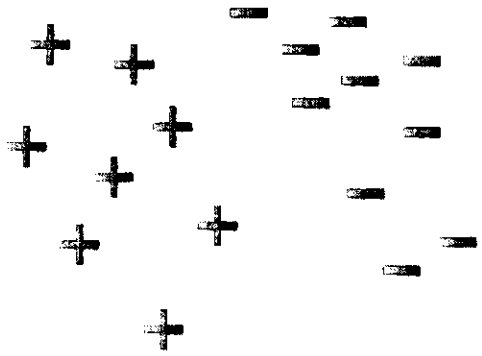
- (5 pts) When is an auto-encoder equivalent to PCA?

- (10 pts) Draw an auto encoder for the case that the inputs are $x \in \Re^8$ and we want to perform dimensionality reduction to have $z \in \Re^3$. What is the output of this auto-encoder? How many weights does this model have? What is the loss function you would use to train this network? How would you do regularization in the auto-encoder?

4. SVMs [25 points].

- (5 pts) What is the primal optimization problem of an SVM? Write the exact equations and explain what they mean.

- (10 pts) Geometric interpretation of an SVM: draw w, the margin, the support vectors and the decision boundary on the following figure.

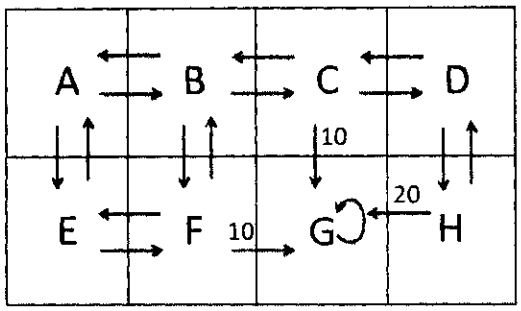


Explain also in words what w, the margin and the support vectors are, as well as why the shape of the decision boundary is what you draw.

- (5 pts) When would you optimize the primal and when the dual optimization problem of an SVM? Why?

- (5 pts) What is a "kernel" in SVM?

5. Reinforcement Learning [20 points].



Consider the robot navigation task shown above. The possible actions in each state are depicted by the arrows. The rewards are $+10$ for moving into state G from F and C, and $+20$ from H. State G is the absorbing (end) state. The reward for moving into every other state is 0.

- (5 pts) Assume that the state transitions are deterministic. Recall that under the simple Q-learning algorithm, the estimated Q values are updated using the following rule:

$$\hat{Q}(s,a) = r(s,a) + \gamma \max_{a'} \hat{Q}(s',a')$$

Consider applying this algorithm when all the $\hat{Q}$ values are initialized to zero, and $\gamma = 0.9$. Write all the Q estimates on the upper figure, after the robot has executed the following state sequences: ABCG, AEFG, DHG.

- (5 pts) During learning, what is a good way of picking an action when in a particular state? Explain your answer.

- (5 pts) What is a value function in reinforcement learning? How does it relate to Q?

- (5 pts) What is a policy in reinforcement learning? By knowing Q, can I compute the policy?

Total Pages = 10

Total Marks = 115