Queen Mary
University of London

ECS629U-759P: ARTIFICIAL INTELLIGENCE

2019/20 – Semester 2

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Coursework 2 (13%): Logic, Classification and Probabilities

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DUE DATE: PLEASE REFER TO THE EXACT DATE FROM QMPLUS
NO LATE submission is allowed: submission link will disappear upon deadline!

Instructions: The coursework is composed of three questions. Only the second exercise (on classification) involves programming, the two others are writing exercises about logic and probabilities. You are expected to submit two files ONLY through the QM+ submission link:

1. A single **PDF** file that must be **at most 5 pages long**. Any file submitted under the wrong format (e.g. `doc`, `docx`, `odt`, etc.) or exceeding the length limit will be penalised. The PDF can include scans of handwritten material as long as it is legible but a typewritten version is encouraged (even better if you use LaTeX). **ATTENTION: Do not include the text of the question in your answers. Failure to do so may disqualify your submission!**

2. A *single compressed folder* containing all your (well documented and sufficiently commented) codes. The code should be written using `Python`. Your code should run (no bugs!). There must be an easy to follow `readme.txt` file inside the folder.

It is allowed to use codes from online resources. However, this has to be clearly cited with reference in your report. Collaboration is NOT permitted when attempting the answers. High level discussion when not attempting the questions may be fine, but discouraged. A better means is using our discussion forum on QM+. There is zero tolerance policy for cases of plagiarism. If in doubt, ask! Please be aware that systems can be busy and slow to respond shortly before deadlines. So you should aim to submit at least one hour before the announced deadline.

Question	Points	Score
Crystal clear! (Logic problem)	40	
Lost in the closet (Classification)	40	
All about the weather (Probabilities)	20	
Total:	100	

Question 1: Crystal clear! (Logic problem) .....

Although you are looking for it everywhere, you cannot find your true love. A bit desperate, you decide to see Madame Irma the most famous (and serious) fortune teller of the city. On the entrance you see a sign stating: **Everything that I say must be proved to be believed**. More perplexed than ever, you still go inside. After glaring at you for some time, she looks into her crystal ball, which has a strange glow, and says in a mysterious voice:

- *You have a dog.*
- *The person you are looking for buys carrots by the bushel.*
- *Anyone who owns a rabbit hates anything that chases any rabbit.*
- *Every dog chases some rabbit.*
- *Anyone who buys carrots by the bushel owns either a rabbit or a grocery store.*
- *Someone who hates something owned by another person will not date that person.*

The sentences you just heard reminds you of a person: Robin. But before you leave, she challenges you with a conclusion:

- *If the person you are looking for does not own a grocery store, she will not date you.*

Remembering the sentence at the entrance, you realise that what she has told you is true only if you can prove her challenge conclusion. Since you don't want any awkward situation, you decide to provide a proof for her conclusion before going to see Robin.

(a) (10 points) Express Madame Irma's six statements into First Order Logic (FOL).
Note: You are allowed to change *the person you are looking for* to *Robin*.

(b) (5 points) Translate the obtained expressions to Conjunctive Normal Forms (CNFs)

(c) (5 points) Transform Madame Irma's conclusion into FOL, negate it and convert it to a CNF.

(d) (20 points) Based on all the previously created CNF (you should have at least 7 depending on how you split them), prove that Madame Irma is right and that you should go to see Robin to declare to her your (logic) love.

Question 2: Lost in the closet (Classification) .....

You are an artist who secluded yourself for years to come up with the perfect design for a new brand of clothes. However, your time off civilisation was not so beneficial since you cannot distinguish a T-shirt from a dress or a sneaker from a sandal any more! In order to redress (!) that issue, you choose to train a Convolutional Neural Network (using `PyTorch`) that will help you identify each cloth to match the perfect design you created. In order to train it, you decide to rely on the dataset fashion MNIST.

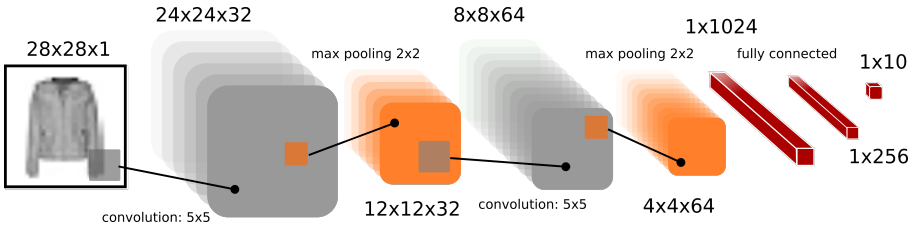
You can access the data using the following lines:

```
import torchvision
import torchvision.transforms as transforms
import torch

train_set = torchvision.datasets.FashionMNIST(root = ".", train = True,
                download = True, transform = transforms.ToTensor())
test_set = torchvision.datasets.FashionMNIST(root = ".", train = False,
                download = True, transform = transforms.ToTensor())

training_loader = torch.utils.data.DataLoader(train_set, batch_size = 32,
                shuffle = False)
test_loader = torch.utils.data.DataLoader(test_set, batch_size = 32,
                shuffle = False)

torch.manual_seed(0)
# If you are using CuDNN, otherwise you can just ignore
torch.backends
torch.backends
```

This class combines LogSoftmax and NLLLoss into a single classhttps://medium.com/udacity-py

(a) (10 points) Given the problem, what is the most appropriate loss function to use?

(b) (10 points) Create and train a Convolutional Neural Network corresponding to the following architecture:



For training, initialise your weights using the *Xavier* **normal** initialisation, use *ReLU* as the activation function, a learning rate of 0.1 with the *SGD* optimiser. You will train your neural network over 50 epochs. What is the final (train and test) accuracy obtained? Provide a plot with the accuracy on the training and test set for each epoch. Looking at the loss through the epochs, discuss what you observe.

(c) (10 points) Now, change the activation function to *Tanh*, *Sigmoid* and *ELU*. Provide only the final classification accuracy. Keeping *ReLU*, use 5 different learning rates: 0.001, 0.1, 0.5, 1, 10. What do you observe? Explain.

(d) (10 points) Now, add a dropout of 0.3 rate on the second fully connected layer. What is the impact of dropout on the performance? Provide the plot for training and test after each epoch. What happens if you decrease or increase the dropout rate?

Question 3: All about the weather (Probabilities) .....

Congratulations, you just graduated and are now officially a physician. You decide to start your career in *Neverland*, a planet on which we can get only three meteorological conditions: *rainy*, *sunny* or *windy* with probabilities 0.25, 0.6, 0.15, respectively.

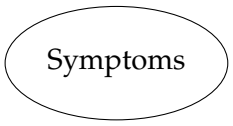
It is known that people there are very affected by the weather (W). As a matter of fact, people suffer from allergies ($Aller$) with probability 0.15 when it's rainy, with probability 0.6 when it's windy, and with probability 0.5 when it's sunny. Independently, the weather can also lead to sickness ($Sick$) with a probability of 0.8 when raining, 0.45 when the wind is blowing and 0.15 when it's sunny. The previous doctor left you this note stating that all the patients you are going to examine will exclusively have one of the following symptoms (S): Headache ($headache$), Runny Nose ($runny$) and Stomachache ($stom$).

(a) (5 points) Draw the Bayesian Network corresponding to this problem, knowing that the terminal node corresponds to symptoms.

(b) (5 points) After a while, you discover in your office a dusty paper left by your predecessor containing the probability of appearance of each symptoms given that the patient is sick and/or allergic.

$Aller$	$Sick$	$\mathbb{P}(S = headache)$	$\mathbb{P}(S = runny)$	$\mathbb{P}(S = stom)$
true	true	0.6	0.3	0.1
true	false	0.75	0.2	0.05
false	true	0.1	0.5	0.4
false	false	0.15	0.05	0.8

You decide to add this information with the terminal node of your network as follow:



$Aller$	$Sick$	$\mathbb{P}(S = headache)$	$\mathbb{P}(S = runny)$	$\mathbb{P}(S = stom)$
true	true	0.6	0.3	0.1
true	false	0.75	0.2	0.05
false	true	0.1	0.5	0.4
false	false	0.15	0.05	0.8

Following the same format, add the conditional probabilities to each node of the network.

(c) (10 points) Knowing that today is sunny, what is the probability of having a patient with a headache but not suffering from allergies? In other words what is the value of $\mathbb{P}(S = headache, Aller = false|W = sunny)$? You should provide all the important steps of your reasoning.

(d) (10 points (bonus)) What is the probability of having a patient showing up complaining from stomachache knowing that it is raining (i.e $\mathbb{P}(S = stom|W = rainy)$)? Once again you should provide all important steps leading to your answer.