

**FINAL EXAM**  
**ECEN 446 - Neural Networks**  
**Information Theory, Inference, and Learning Algorithms**

*Joseph J. Boutros, 11 July 2021*

**Three Problems in Inference and Neural Networks (100 points)**

Textbooks, lecture notes, scientific calculators are allowed. Laptops and tablets are only authorized for consulting class notes, for visiting ECEN 446 web page, and for running Jupyter-Notebook, Python 3, Pari/gp or WolframAlpha/Mathematica software. Cellphones and chat applications are forbidden, they should stay away from your desk. Total time duration is 120 minutes.

**Part I - Information Theory (20 points)**

We recall that, for a discrete random variable  $X \in \mathcal{X} = \{x_1, x_2, \dots, x_M\}$ , the entropy of  $X$  is defined as

$$\begin{aligned} H(X) &= - \sum_{x \in \mathcal{X}} \mathbb{P}(X = x) \log(\mathbb{P}(X = x)) \\ &= - \sum_{x \in \mathcal{X}} p_X(x) \log(p_X(x)) = - \sum_{i=1}^M p_i \log(p_i), \end{aligned} \quad (1)$$

where  $p_X(x)$  is the probability mass function of  $X$  and  $p_i = \mathbb{P}(X = x_i) = p_X(x_i)$ ,  $i = 1 \dots M$ . Here, the integer  $M$  could be finite or infinite (to be replaced by  $\infty$ ), e.g. if  $X$  is Poisson. For continuous random variables, we recall the similar definition of differential entropy

$$h(X) = - \int_{-\infty}^{\infty} p_X(x) \log(p_X(x)) dx, \quad (2)$$

where  $p_X(x)$  is the probability density function of  $X$ ,  $X \in \mathbb{R}$ .

**(a)** Let  $X_1 \sim \text{Bernoulli}(p_1)$  and  $X_2 \sim \text{Bernoulli}(p_2)$ ,  $X_1$  and  $X_2$  independent. Define  $S = X_1 + X_2$ , where the sum is modulo 2. Find the expression of the entropy of  $S$  as a function of  $p_1$  and  $p_2$ .

Hint: Determine  $\mathbb{P}(S = 0)$  and  $\mathbb{P}(S = 1)$ .

**(b)** Compute  $H(S)$  for  $p_1 = 1/2$  and any  $p_2$ . Compute  $H(S)$  for  $p_1 = p_2 = 1/4$ . Does the entropy increase after modulo 2 addition?

Hint: Compare  $H(S)$  to  $H(X_1)$ .

**(c)** Now  $S = X_1 + X_2$  where  $+$  is the standard addition in  $\mathbb{R}$ . The two random variables are not independent, their joint distribution is given by the following table

# Neural Networks Final Exam

**SJ Ball**



## **Neural Networks Final Exam:**

## **Neural Networks Final Exam** Book Review: Unveiling the Magic of Language

In an electronic digital era where connections and knowledge reign supreme, the enchanting power of language has become more apparent than ever. Its capability to stir emotions, provoke thought, and instigate transformation is truly remarkable. This extraordinary book, aptly titled "**Neural Networks Final Exam**," published by a highly acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound impact on our existence. Throughout this critique, we shall delve to the book's central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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