

**IE534/CS547: Deep Learning**

**(Due: Mar-4-2021)**

## Homework #4

*Instructor:* Richard B. Sowers

Read all the instructions below carefully before you start working on the assignment, and before you make a submission.

- **This is a group homework, every group only submit ONE solution on Compass .** Please include the names of all the group members.
- **Due time is at 11:59pm** at the due date. **No late submission!**
- All students are expected to abide by the Honor Code
- All date-times will be in Champaign-Urbana
- Please put your typed solution in a PDF format. For code, you should submit a google colab notebook link with viewers permission to instructors and TAs in your solution PDF file.

### Problem 1: Backpropsimple

(10 points)

Define

$$\phi(x) \stackrel{\text{def}}{=} \cos(2x). \quad x \in \mathbb{R}$$

Define

$$f(m) \stackrel{\text{def}}{=} \exp[\pi\phi(mx)]$$

for  $m \in \mathbb{R}$ . Set  $x = 5$ , and compute  $f'(10)$ .

### Problem 2: Backprop

(10 points)

Define

$$\phi_n(x) \stackrel{\text{def}}{=} \cos(2^n x) \quad x \in \mathbb{R}$$

for  $n \in \{1, 2, 3\}$ . Set  $x = 5$  and define

$$f_5(m_1, m_2, m_3) \stackrel{\text{def}}{=} \exp[\pi\phi_3(m_3\phi_2(m_2\phi_1(m_1x)))]$$

for  $(m_1, m_2, m_3) \in \mathbb{R}^3$ .

- Compute  $\frac{\partial f_5}{\partial m_3}(10, 9, 8)$
- Compute  $\frac{\partial f_5}{\partial m_2}(10, 9, 8)$
- Compute  $\frac{\partial f_5}{\partial m_1}(10, 9, 8)$

### Problem 3: BackpropConstants

(10 points)

Define

$$\phi_n(x) \stackrel{\text{def}}{=} \cos(2^n x) \quad x \in \mathbb{R}$$

for  $n \in \{1, 2, 3\}$ . Set  $x = 5$  and define

$$f_5(m_1, b_1, m_2, b_2, m_3, b_3) \stackrel{\text{def}}{=} \exp[\pi\phi_3(m_3\phi_2(m_2\phi_1(m_1x + b_1) + b_2) + b_3)]$$

for  $(m_1, b_1, m_2, b_2, m_3, b_3) \in \mathbb{R}^6$ .

- Compute  $\frac{\partial f_5}{\partial m_3}(10, 11, 9, 19, 8, 18)$
- Compute  $\frac{\partial f_5}{\partial m_2}(10, 11, 9, 19, 8, 18)$

(c) Compute  $\frac{\partial f_5}{\partial m_1}(10, 11, 9, 19, 8, 18)$

<b>Problem 4: Coding Question</b>
-----------------------------------

(10 points)

Define  $\Phi_n(x) = \cos 2^n x$  for  $x \in \mathbb{R}$  and  $n \in 1, 2, 3$ . Set  $x = 5$  and define

$$f_5(m_1, m_2, m_3) \stackrel{\text{def}}{=} \exp[\pi \phi_3(m_3 \phi_2(m_2 \phi_1(m_1 x)))]$$

for  $(m_1, m_2, m_3) \in \mathbb{R}^3$ .

- Numerically compute  $\lim_{\epsilon \rightarrow 0} \{f_5(10, 9, 8 + \epsilon) - f_5(10, 9, 8)\}/\epsilon$ .
- Numerically compute  $\lim_{\epsilon \rightarrow 0} \{f_5(10, 9 + \epsilon, 8) - f_5(10, 9, 8)\}/\epsilon$ .
- Numerically compute  $\lim_{\epsilon \rightarrow 0} \{f_5(10 + \epsilon, 9, 8) - f_5(10, 9, 8)\}/\epsilon$ .