Exercise Sheet 5

Neural Computation
University of Birmingham

Week 5 2025

Exercise 1. You are given a mini-batch of two single-channel images, each of size 2×2:

$$X^{(1)} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}, \quad X^{(2)} = \begin{bmatrix} -1 & -2 \\ -3 & -4 \end{bmatrix}$$

Assume batch normalisation is applied. Let:

- $\gamma = 1$
- $\beta = 0$
- $\epsilon = 10^{-5}$ (is negligible here)

1. Compute the result of applying batch normalisation to this mini-batch.
2. Assume that the images are normalised using min-max normalisation, **using the min and max of the full batch** before they go into the batch norm layer. What is the result after the min-max normalisation and after the subsequent batch norm?
3. Assume that the images are separately normalised using min-max normalisation, **using the min and max of each image** before they go into the batch norm layer. What is the result after the min-max normalisation and after the subsequent batch norm?
4. What are the learnable parameters in batch normalisation?
5. How many learnable parameters are there in this example?
6. How would the number of learnable parameters change if:
   - The input images had 16 channels?
   - The spatial dimensions of the images were larger, 32×32?

Exercise 2. You are given a row of three pixel values:

$$[0,\ 100,\ 0]$$

Your task is to upscale this row to a length of 6 pixels using **linear interpolation**, aligning the **outer edges** of the pixels (not the pixel centres).

Compute the upscaled 6-pixel row using linear interpolation.