

# IDL Exercise 2.

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## 1 Theoretical Questions:

### 1.1 LTI.

Show that a convolution with respect to any filter  $h$  is time/space invariant.

**Solution.** Let's denote by  $\mathcal{L} : \text{funcs} \rightarrow \text{funcs}$  the convolution by the filter  $h$ , namely  $\mathcal{L}[f] = f * h = \sum_x h(x)f(y-x)$ . To show that  $\mathcal{L}$  is an LTI operation we have to show that  $\mathcal{L}[f(x-t)](y) = \mathcal{L}[f](y-t)$ . (Notes that the linearity we got for free by the linearity of convolution, So only the time invariant part is left). So:

$$\begin{aligned}\mathcal{L}[f(x-t)](y) &= f(x-t) * h = \sum_x h(x)f(\overbrace{y-t}^{\tau}-x) = \sum_x h(x)f(\tau-x) \\ &= \mathcal{L}[f](\tau) = \mathcal{L}[f](y-t)\end{aligned}$$

And we got that the convolution is an LTI operation.

### 1.2 TI.

Explain whether each of the following layers are time/space invariant or not:

1. Additive constant.

**Solution. TRUE.**  $\mathcal{L}[f] = f(x) + c \Rightarrow \mathcal{L}[f(x-t)] = f(x-t) + c = \mathcal{L}[f](x-t)$

2. Pointwise nonlinearity (such as ReLU) **Solution.**

3. Strided pooling by a factor  $> 1$  **Solution.**

4. As a result, is a CNN composed of all these operators (+convolution) time invariant? **Solution.**

### 1.3 Layers' Jacobian.

Calculate the Jacobian matrix of the following layers:

1. Additive bias vector
2. General Matrix multiplication
3. Convolution layer