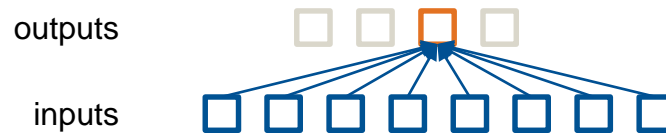# Structured Data

- "Zero-dimensional" data: multilayer perceptron

- Structured data: translation-covariant operations
  - Neighborhood structure: convolutional networks (2D/3D images, 1D bio. sequences, …)

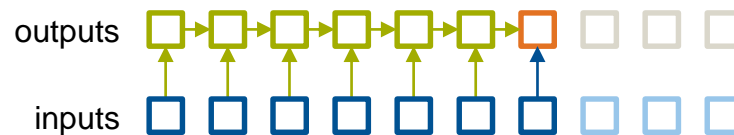 - Sequential structure (memory): recurrent networks (1D text, 1D audio, …)

Structured Data

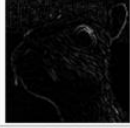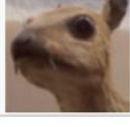- "Zero-dimensional" data: multilayer perceptron

- Structured data: translation-covariant operations
  - Neighborhood structure: convolutional networks (2D/3D images, 1D bio. sequences, …)

  - Sequential structure (memory): recurrent networks (1D text, 1D audio, …)
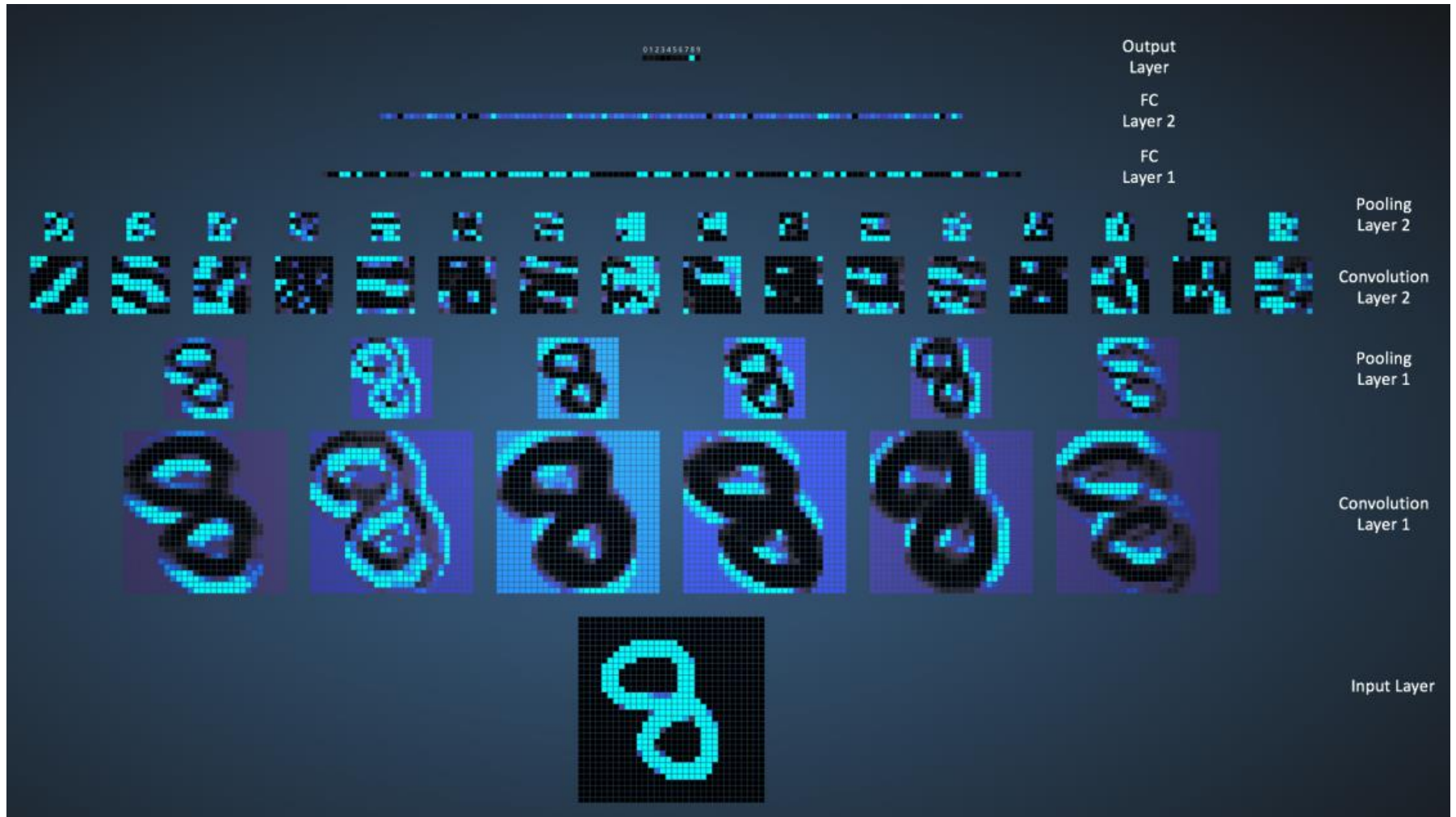
Convolution with Handcrafted Filters

Operation	Filter	Convolved Image
Identity	$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$	
Edge detection	$\begin{bmatrix} 1 & 0 & -1 \\ 0 & 0 & 0 \\ -1 & 0 & 1 \end{bmatrix}$	
	$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$	
	$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$	
Sharpen	$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$	
Box blur (normalized)	$\frac{1}{9} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$	
Gaussian blur (approximation)	$\frac{1}{16} \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$	

The shown filters are handcrafted

Learned filters are optimal
- In terms of the training set
- In the context of all network layers (optimized jointly)

https://en.wikipedia.org/wiki/Kernel_(image_processing)

Convolutional Network

http://scs.ryerson.ca/~aharley/vis/

References

Convolutional Neural Networks:

https://ujjwalkarn.me/2016/08/11/intuitive-explanation-convnets/

Recurrent Neural Networks:

http://karpathy.github.io/2015/05/21/rnn-effectiveness/

http://colah.github.io/posts/2015-08-Understanding-LSTMs/