Autoencoders

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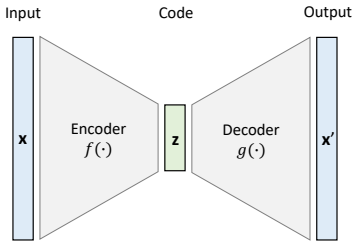
COMP 4211: Machine Learning (Fall 2022)

1. Conventional Autoencoders
2. Denoising Autoencoders
3. Convolutional Autoencoders
4. Further Study

An Alternative Way of Achieving Dimensionality Reduction

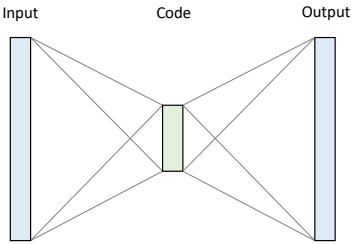


- We can use a special feedforward neural network with a bottleneck layer for dimensionality reduction:

$$\mathbf{z} = f(\mathbf{x})$$
$$\mathbf{x}' = g(\mathbf{z}) = g(f(\mathbf{x})) \approx \mathbf{x},$$

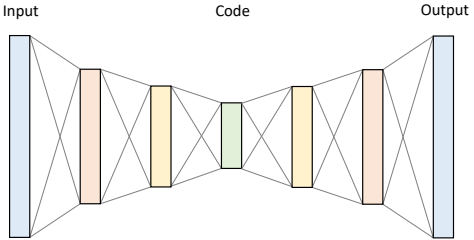
where the input $\mathbf{x} \in \mathcal{R}^d$, the code $\mathbf{z} \in \mathcal{R}^h$, and $h < d$.

Simple Autoencoders



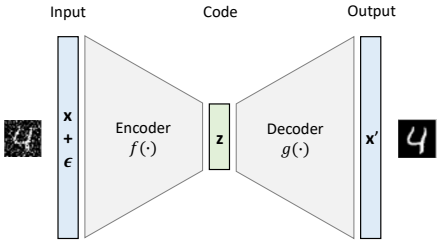
- If the encoder $f(\cdot)$ and decoder $g(\cdot)$ are linear functions and the squared loss is used by minimizing $\left\|g(f(\mathbf{x})) - \mathbf{x}\right\|_2^2$ over all inputs $\mathbf{x}$, then the code $\mathbf{z}$ learned spans the same h-dimensional subspace as PCA.
- Essentially it provides an alternative way of performing PCA.

Deep Autoencoders



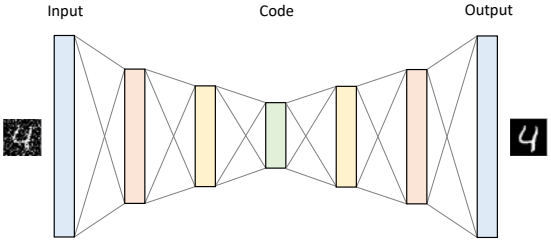
- Deep autoencoders are autoencoders with more layers added to the encoder and decoder.
- It is essential that nonlinear activation functions are used in the encoder and decoder.
- More compact codes can be learned.

Denoising Autoencoders



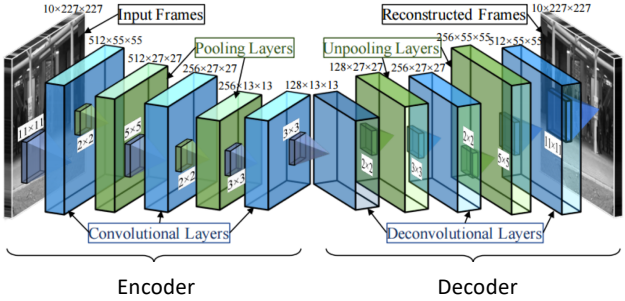
- Noise ϵ is added to the original (clean) input $\mathbf{x}$ to result in the new (noisy) input $\mathbf{x} + \epsilon$ which is fed into the denoising autoencoder.
- By learning to recover the clean input $\mathbf{x}$, it can give a more robust code which is less sensitive to input noise.

Stacked Denoising Autoencoders



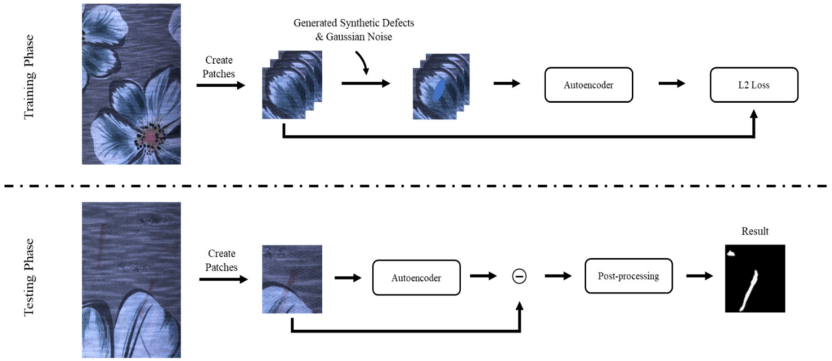
- When a denoising autoencoder involves a deep neural network, it is also called a stacked denoising autoencoder.

Convolutional Autoencoders



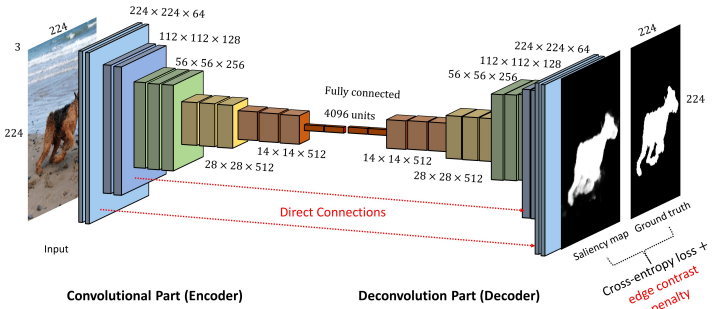
- Like other autoencoders, a convolutional autoencoder has an encoder and a decoder.
- While the encoder consists of convolutional and pooling layers, the decoder consists of deconvolutional and unpooling layers.

Convolutional Autoencoders for Defect Detection



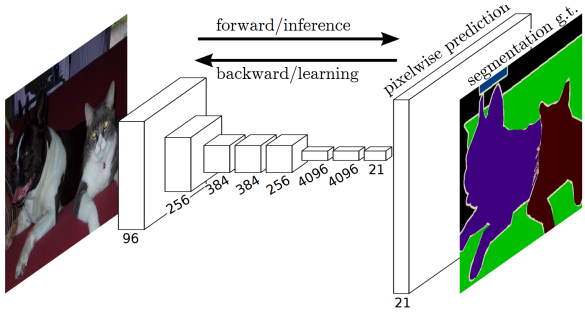
- Defects in the anomalous images cannot be recovered well by the autoencoder and hence can be detected.

Generalizing Convolutional Autoencoders for Image Segmentation



- If the target output is not the input itself but a segmentation mask, convolutional autoencoders can also be used for image segmentation applications.

Further Generalization to Fully Convolutional Networks



- Convolutional autoencoders have also been further generalized to fully convolutional networks which have no clear separation into an encoder and a decoder.
- Fully convolutional networks are mainly used for image segmentation applications such as semantic segmentation.

To Learn More...

- Variational autoencoders