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### AI 101



Updated 11 months ago on September 20, 2020

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# What is an Autoencoder?

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If you've read about unsupervised learning techniques before, you may have heard of autoencoders. Autoencoders are one of the primary ways that unsupervised learning is used. What exactly is an autoencoder exactly?

Briefly, autoencoders operate by taking in data, compressing and encoding it, and then reconstructing the data from the encoding representation. The model is trained until the reconstructed data is as closely as possible to the original data. That's a quick definition of an autoencoder, it would be beneficial to take a deeper look at a better understanding of how they function. This article will endeavor to provide a detailed architecture of autoencoders and their applications.

## What is an Autoencoder?

Autoencoders are neural networks. Neural networks are composed of layers of nodes. In an autoencoder, the input layers contain exactly as much information as the output layers. The input layer and output layer has the exact same number of units is the number of units in the input data. It outputs a copy of the data after analyzing it and reconstructing it.

The data that moves through an autoencoder isn't just mapped straight through. The network doesn't just copy the input data. There are three components to an autoencoder: a component that compresses the data, a component that handles the compressed data, and a component that reconstructs the data. When data is fed into an autoencoder, it is encoded and the network is then trained on the encoded/compressed data and it outputs a reconstructed version of the data.



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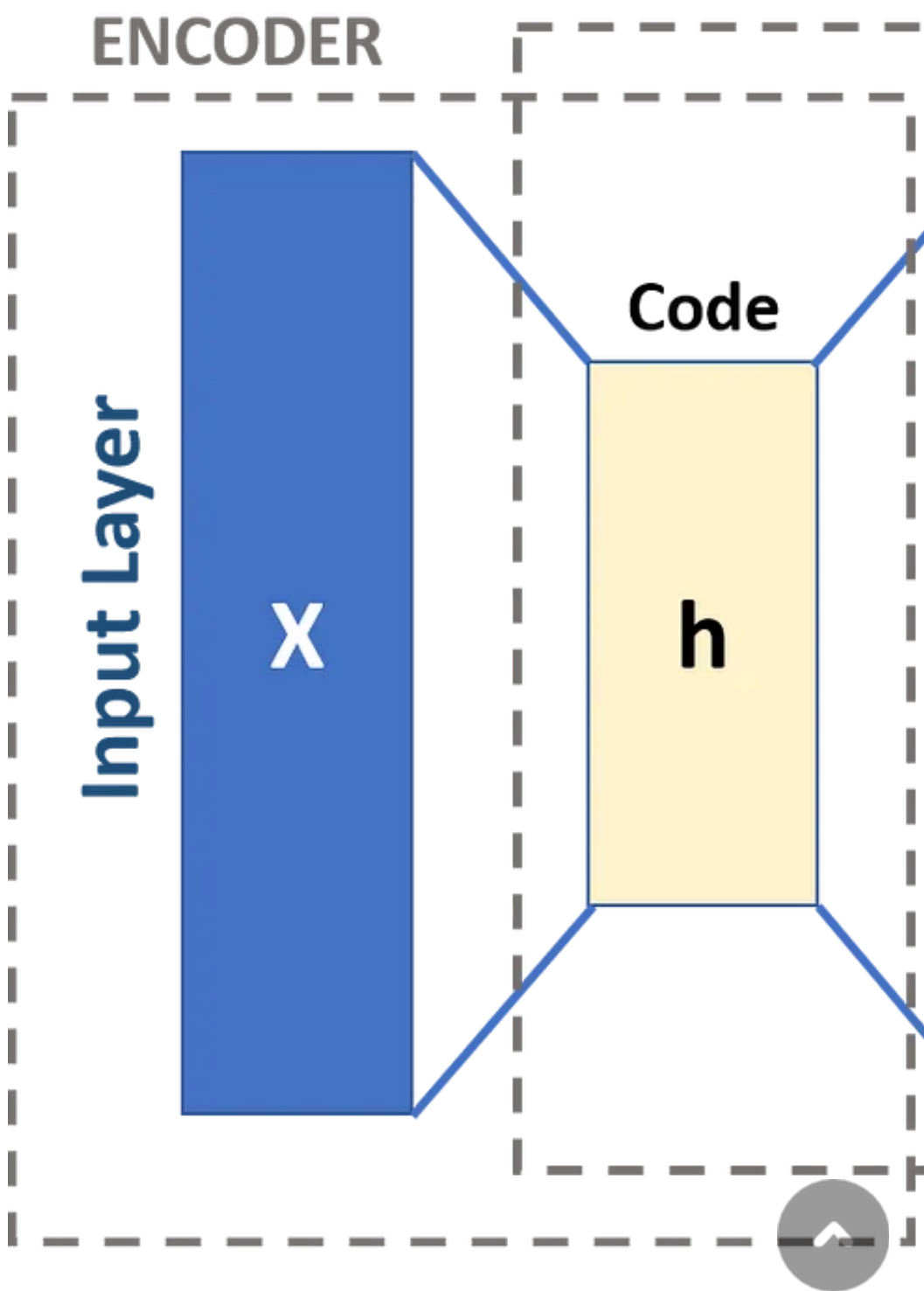
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So why would you want to train a network to just reconstruct the data? A neural network learns the “essence”, or most important features of the input data. A generative model can be created that can synthesize similar data, with the added ability to generate new data. For instance, you could train an autoencoder on grainy images and then generate new images from the image.

## Autoencoder Architecture

Let's take a look at the architecture of an autoencoder. We'll discuss how it works. There are variations on this general architecture that we'll discuss in a later section.



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As previously mentioned an autoencoder can essentially be divided into three parts: the encoder, the bottleneck, and the decoder.

The encoder portion of the autoencoder is typically a feedforward, dense layer. The primary purpose of the encoding layers is to take the input data and compress it into a latent representation of the data that has reduced dimensionality.

The code layers, or the bottleneck, deal with the compressed representation. They are carefully designed to determine the most relevant portions of the original data. The goal is to identify features of the data that are most important for data reconstruction. The bottleneck determines which features of the data need to be preserved and which can be discarded. The bottleneck also takes into account other considerations: representation size (how compact the representation can be), reconstruction quality, and how the bottleneck performs element-wise activation on the weights and biases. The output of the bottleneck is sometimes called a latent representation or latent variables.

The decoder layer is what is responsible for taking the compressed representation and reconstructing it with the same dimensions as the original, unaltered data. The convolutional layer takes the representation that was created by the encoder.

The most basic architecture of an autoencoder is a feed-forward architecture. It is a simple layer perceptron used in multilayer perceptrons. Much like regular feed-forward networks, it is trained through the use of backpropagation.

## Attributes of An Autoencoder

There are various types of autoencoders, but they all have certain properties.

Autoencoders learn automatically. They don't require labels, and if given enough data, an autoencoder can reach high performance on a specific kind of input data.

Autoencoders are data-specific. This means that they can only compress data that the autoencoder has already been trained on. Autoencoders are also lossy, meaning the reconstructed data can be degraded in comparison to the input data.

When designing an autoencoder, machine learning engineers need to consider several hyperparameters: code size, layer number, nodes per layer, and loss function.

The code size decides how many nodes begin the middle portion of the autoencoder. A larger code size means more data more. In a deep autoencoder, while the number of layers can be increased, the code size remains constant.

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appropriate, the number of nodes in a layer should decrease as the true in the decoder, meaning the number of nodes per layer should final layer. Finally, the loss function of an autoencoder is typically either Binary cross-entropy is appropriate for instances where the input variable

## Autoencoder Types

As mentioned above, variations on the classic autoencoder architecture exist. Below are some of the most common autoencoder architectures.

### Sparse

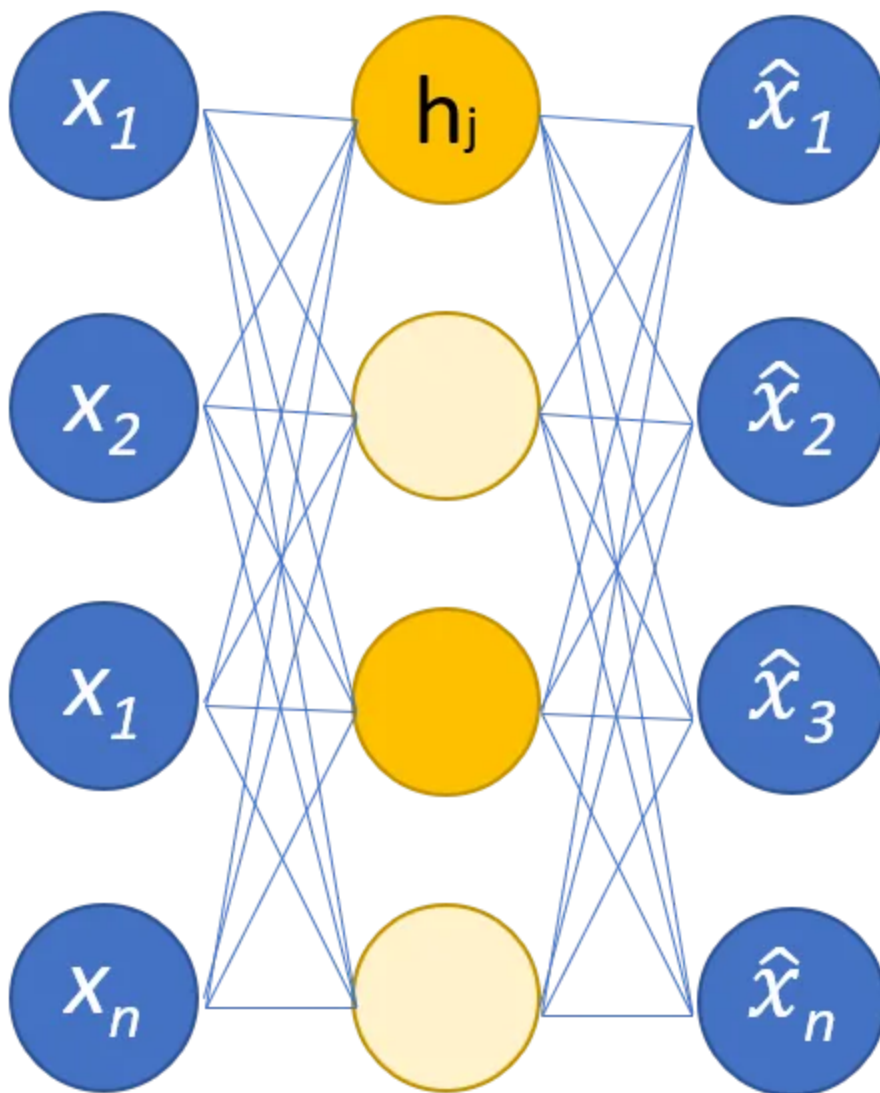


Photo: Michela Massi via Wikimedia Commons, CC BY SA 4.0  
([https://commons.wikimedia.org/wiki/File:Autoencoder\\_sparso.png](https://commons.wikimedia.org/wiki/File:Autoencoder_sparso.png))

While autoencoders typically have a bottleneck that compresses the input into a lower-dimensional latent space, autoencoders are an alternative to that typical operational format. In this variant, the hidden layer is the same size as the encoder and decoder layers. Instead, the activation function is applied to each node in the hidden layer to push it up so the loss function better captures the statistical features of the input data.

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hidden layers of a sparse autoencoder have more units than a traditional fully connected layer. Only a subset of them are active at any given time. The most impactful activation function is the ReLU function. This constraint helps the network determine just the most salient features.

## Contractive

Contractive autoencoders are designed to be resilient against small perturbations in the input data. This is accomplished by applying a penalty to the model's reconstruction. This technique is based on the Frobenius norm of the Jacobian matrix of the reconstruction function. The regularization technique is that the model is forced to construct an encoding that is robust to small changes in the input data.

## Convolutional

Convolutional autoencoders encode input data by splitting the data into small subsections into simple signals that are summed together to create a feature map. In convolution neural networks, a convolutional autoencoder specializes in processing images. A filter that is moved across the entire image section by section. The feature map can be used to reconstruct the image, reflect the image, or modify the image. The features learned by the network, they can be used on any sufficiently similar images.

## Denoising



Photo: MAL via Wikimedia Commons, CC BY SA 3.0  
([https://en.wikipedia.org/wiki/File:ROF\\_Denoising\\_Example.png](https://en.wikipedia.org/wiki/File:ROF_Denoising_Example.png))

Denoising autoencoders introduce noise into the encoding, resulting in a corrupted version of the original input data. This corrupted version of the data is used to train the model to reconstruct the output values with the original input and not the corrupted input. The model is trained to reproduce the original, non-corrupted version of the image. By comparing the reconstructed image to the original, the network learns which features of the data are most important and which are less important. In other words, in order for a model to denoise the corrupted images, it must learn the most important features of the image data.

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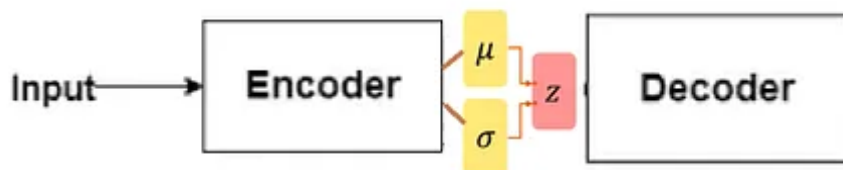
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## Variational

Variational autoencoders operate by making assumptions about how a variational autoencoder produces a probability distribution for the latent attributes. When training, the encoder creates latent distribution



learns the features or images as Gaussian distributions instead of directly generating new images. The Gaussian distribution is sampled to create a latent vector, which renders an image based on this vector of samples. During training, the network takes the training images and assigns them some probability that they will be generated by the network. This is used to reverse engineer an image, generating new images that resemble the training data.

When training the network, the encoded data is analyzed and the mean and standard deviation of the images are calculated. A distribution is created based on these parameters. The decoder then takes random samples from this distribution to reconstruct the initial inputs to the network.

## Autoencoder Applications

Autoencoders can be used for a wide variety of applications, but they are most commonly used for dimensionality reduction, data denoising, feature extraction, image generation, and recommendation systems.

Data denoising is the use of autoencoders to strip grain/noise from images. They can also be used to repair other types of image damage, like blurry images or images with missing parts. Autoencoders can help high capacity networks learn useful features of images, meaning they can be used for the training of other types of neural networks. This is also true of using autoencoders for image generation. Autoencoders can be used to identify features of other training data.

In terms of image generation, autoencoders can be used to generate new images that resemble the training data, which has applications in designing face recognition systems or automatic image captioning.





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Sequence to sequence prediction models can be used to determine the next item in a sequence. An autoencoder can be used to generate the next even in a sequence. to generate videos. Finally, deep autoencoders can be used to create patterns relating to user interest, with the encoder analyzing user embeddings to generate recommendations that fit the established patterns.

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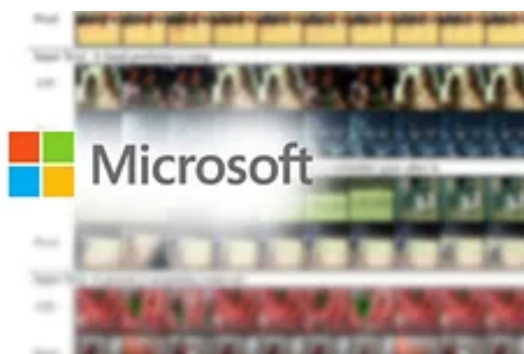


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