GAN & Diffusion Models

Discriminative vs Generative models

A **discriminative** model is a statistical model that determines boundaries in observed data and uses these boundaries to make decisions or predictions (ex: classification and regression models)

A **generative** model describes how a dataset is generated in terms of a probabilistic model, sampling from the model allows us to generate new data that did not exist before (ex: GANS and diffusion models). As they normally works with unlabeled data, they are unsupervised ML.

Generative models are probabilistic in nature rather than deterministic.

Applications of Generative Models

- Upsampling imbalanced datasets
- Imputation of missing values
- Anonymizing sensitive datasets

Generative models

This presentation will focus on 2 types of generative models. Both are unsupervised methods (they are trained on unlabeled data) and both are used to generate images:

- Generative Adversarial Networks (GANs). Meade of two neural networks competing against each other (in a zero sum game). One network is a generator, the other is a discriminator.

  Click here for the original paper (2014)

- Denoising Diffusion Probabilistic Models. Used for high quality image synthesis, it consists of a forward diffusion process incrementally adding noise to an image and of a neural network approximating the reverse diffusion process, thus removing noise to generate the final image.

  Click here for the original paper (2020)

Denoising Diffusion Probabilistic models

These systems are made of two Diffusion processes, both modeled as Markov chains:

- Forward Diffusion. In this process independent Gaussian noise is iterative added to an image with very small increments, until the image becomes pure noise, similar to static.

- Reverse Diffusion. This process reverses the previous one, by incrementally removing noise from initial static, through a large number of iterations, until an image is produced, similar to the image provided in the training dataset, but stochastically generated.

Variational Autoencoders (VAE)

A diffusion model can be compared to a Variational Autoencoder (VAE).

Autoencoders are neural networks generally used for dimensional reduction.

They are able to extract the most significant aspects of a set of data. An input fed into this NN is encoded to a lower dimensionality. Autoencoder are made of an Encoder and a Decoder.

The Encoder extracts the latent features of the input.

Latent feature are then used to regenerate the original input by the Decoder.

While normal Autoencoders are deterministic systems, Variational Autoencoders are probabilistic systems, where a random elements are added in determining their outputs. VAs are therefore Generative in nature.

Forward process of a Diffusion Model

A diffusion model differs from a Variational Autoencoder in the fact that the forward process in fixed.

It requires adding progressive noise to the input,

The neural network of the Encoder therefore does not require training.

Only the Decoder’s neural network needs to be trained.