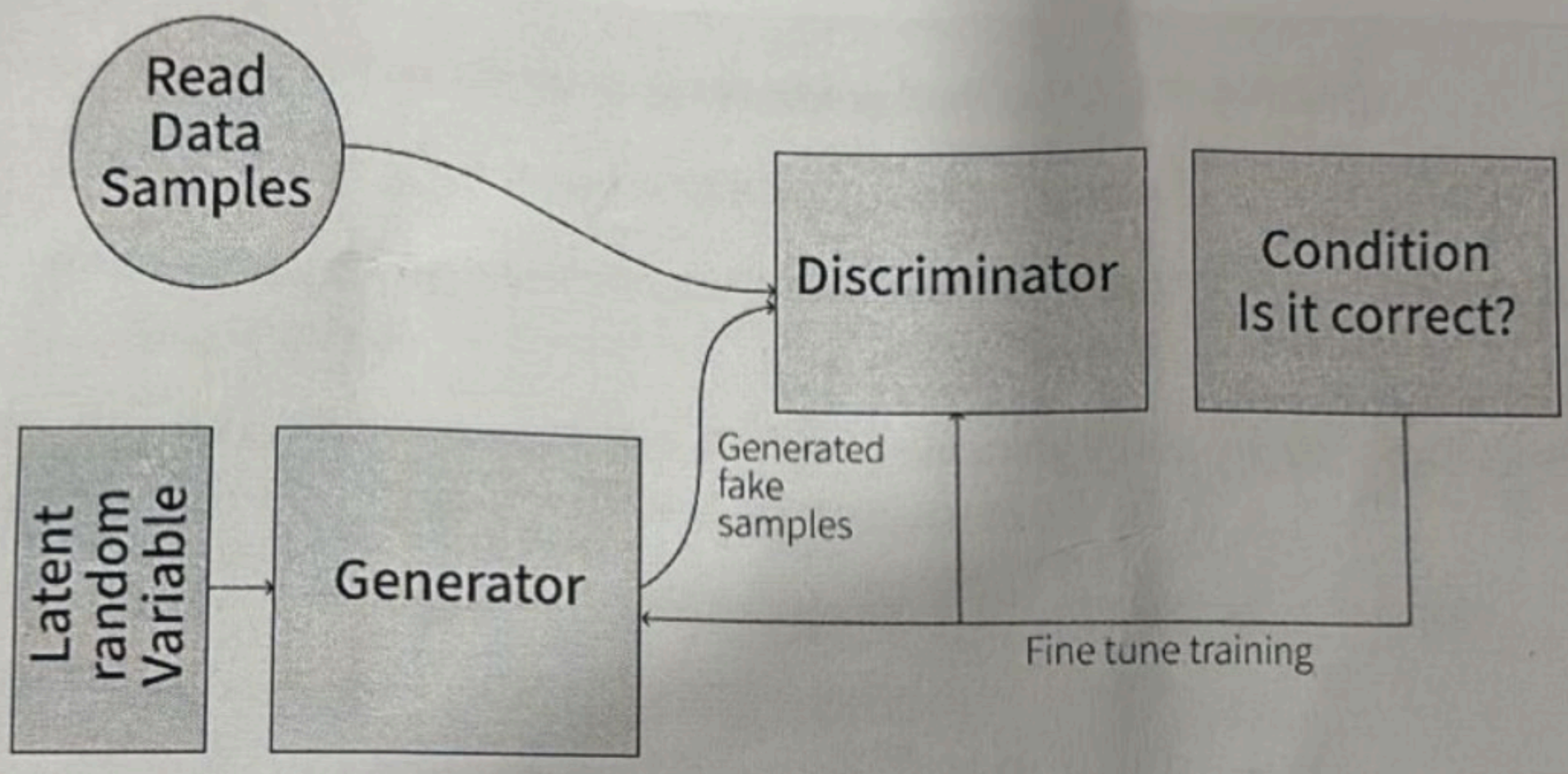
Chapter-10

Generative Adversarial Networks (GAN) help machines to create new, realistic data by learning from existing examples. It is introduced by Ian Goodfellow and his team in 2014 and they have transformed how computers generate images, videos, music and more.

Unlike traditional models that only recognize or classify data, they take a creative way by generating entirely new content that closely resembles real-world data. This ability helped various fields such as art, gaming, healthcare and data science. In this article, we will see more about GANs and its core concepts.



Architecture of GAN

GAN consist of two main models that work together to create realistic synthetic data which are as follows:

1. Generator Model

The generator is a deep neural network that takes random noise as input to generate realistic data samples like images or text. It learns the underlying data patterns by adjusting its internal parameters during training through backpropagation. Its objective is to produce samples that the discriminator classifies as real.

2. Discriminator Model

The discriminator acts as a binary classifier helps in distinguishing between real and generated data. It learns to improve its classification ability through training, refining its parameters to detect fake samples more accurately. When dealing with image data, the discriminator uses convolutional layers or other relevant architectures which help to extract features and enhance the model's ability.

Generator Loss Function: The generator tries to minimize this loss:

~~$J_G = -1/m \Sigma_{i=1}^{m} log D(G(z_i))$~~

$$J_G = -\frac{1}{m}\sum_{i=1}^{m} \log D(G(z_i))$$

- $J_G$measure how well the generator is fooling the discriminator.
- $G(z_i)$ is the generated sample from random noise z_i
- $D(G(z_i))$ is the discriminator's estimated probability that the generated sample is real.

The generator aims to maximize $D(G(z_i))$ meaning it wants the discriminator to classify its fake data as real (probability close to 1).

Discriminator Loss Function: The discriminator tries to minimize this loss:

~~$J_D = -1/m \Sigma_{i=1}^{m} log D(x_i) - m1 \Sigma_{i=1}^{m} log(1 - D(G(z_i))$~~

$$J_D = -\frac{1}{m}\sum_{i=1}^{m} \log D(x_i) - \frac{1}{m}\sum_{i=1}^{m} \log(1 - D(G(z_i))$$

The discriminator wants to correctly classify real data as real (maximize $logD(x_i)$ and fake data as fake (maximize $log(1 - D(G(z_i)))$

= discriminator classifies real/fake sample
= data sample, $D(x_i)$ = discriminators probability that x_i is real.

Adversarial Learning

- If the discriminator correctly classifies real and fake data it gets better at its job.
- If the generator fools the discriminator by creating realistic fake data, it receives a positive update and the discriminator is penalized for making a wrong decision.

Generator's Improvement

- Each time the discriminator mistakes fake data for real, the generator learns from this success.
- Through many iterations, the generator improves and creates more convincing fake samples.

Discriminator's Adaptation

- The discriminator also learns continuously by updating itself to better spot fake data.
- This constant back-and-forth makes both networks stronger over time.

Training Progression

- As training continues, the generator becomes highly proficient at producing realistic data.
- Eventually the discriminator struggles to distinguish real from fake shows that the GAN has reached a well-trained state.
- At this point, the generator can produce high-quality synthetic data that can be used for different applications.

Sample Question

- What is the role of the hidden state h_t in RNN?
- Define sequence-to-sequence learning with an example.
- Write the equation of the input gate in LSTM.
- What is vanishing gradient problem in RNN?
- What does the initial hidden state h_0 represent?
- How does LSTM overcome the vanishing gradient problem?
- Explain the working principle of RNN with a neat diagram.
- What is the function of the forget gate?
- What is a Generative Adversarial Network?
- Name the two main components of GAN.
- What is the objective of the discriminator?
- Explain GAN architecture with generator and discriminator.
- Describe the GAN training process.
- Compare RNN and LSTM

→ what activation function is used in LSTM gates?