Generative Adversarial Network

Zeham Management Technologies BootCamp by SDAIA

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SDAIA
الهيئة السعودية للبيانات والذكاء الاصطناعي
Saudi Data & AI Authority

Agenda

Introduction to Generative Adversarial Networks (GANs)

Generator

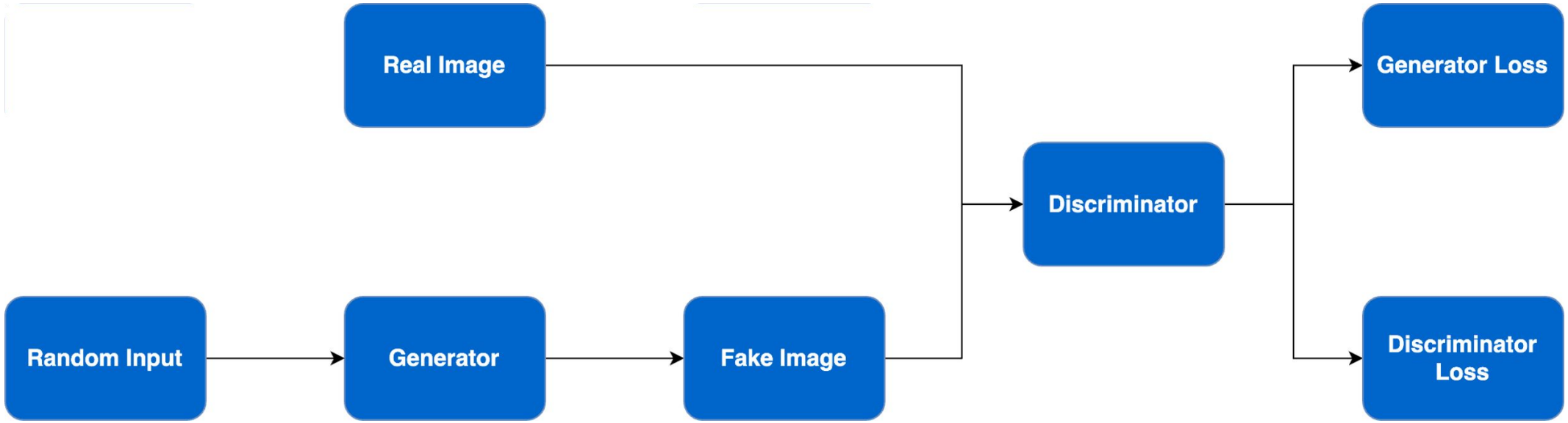
Discriminator

How does GANs work?

Introduction to Generative Adversarial Networks (GANs)

What are GANs?

Generative Adversarial Networks (GANs) are a class of machine learning frameworks designed by Ian Goodfellow and his colleagues in 2014. GANs consist of two neural networks, a Generator and a Discriminator, that are trained simultaneously through an adversarial process.



Applications of GANs

- Image Generation
- Data Augmentation
- Style Transfer
- Image-to-Image Translation
- Super-Resolution
- Text-to-Image Synthesis
- Video Generation

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Applications of GANs (Human Faces)

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Applications of GANs (Objects)

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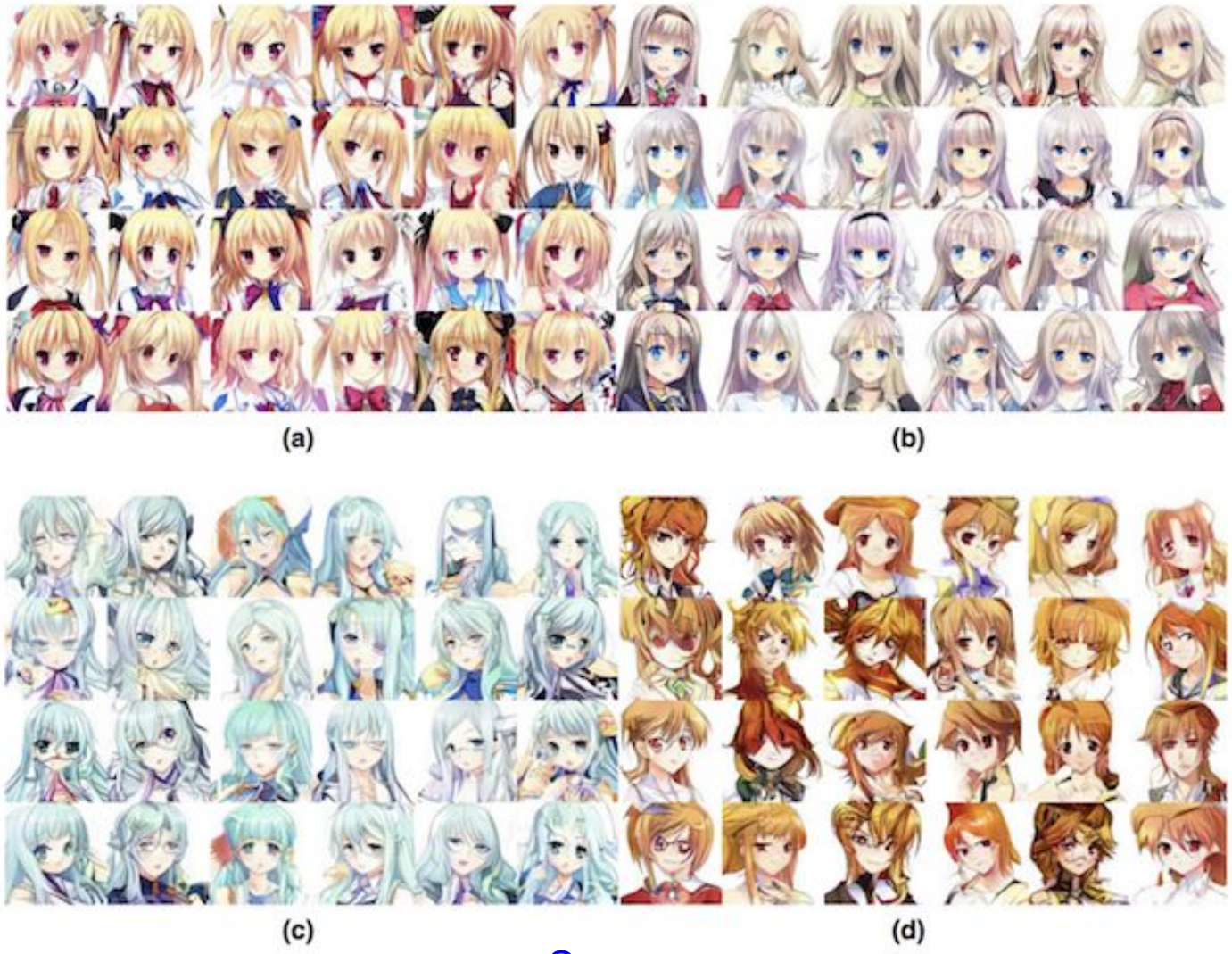
Applications of GANs (Cartoon Characters)



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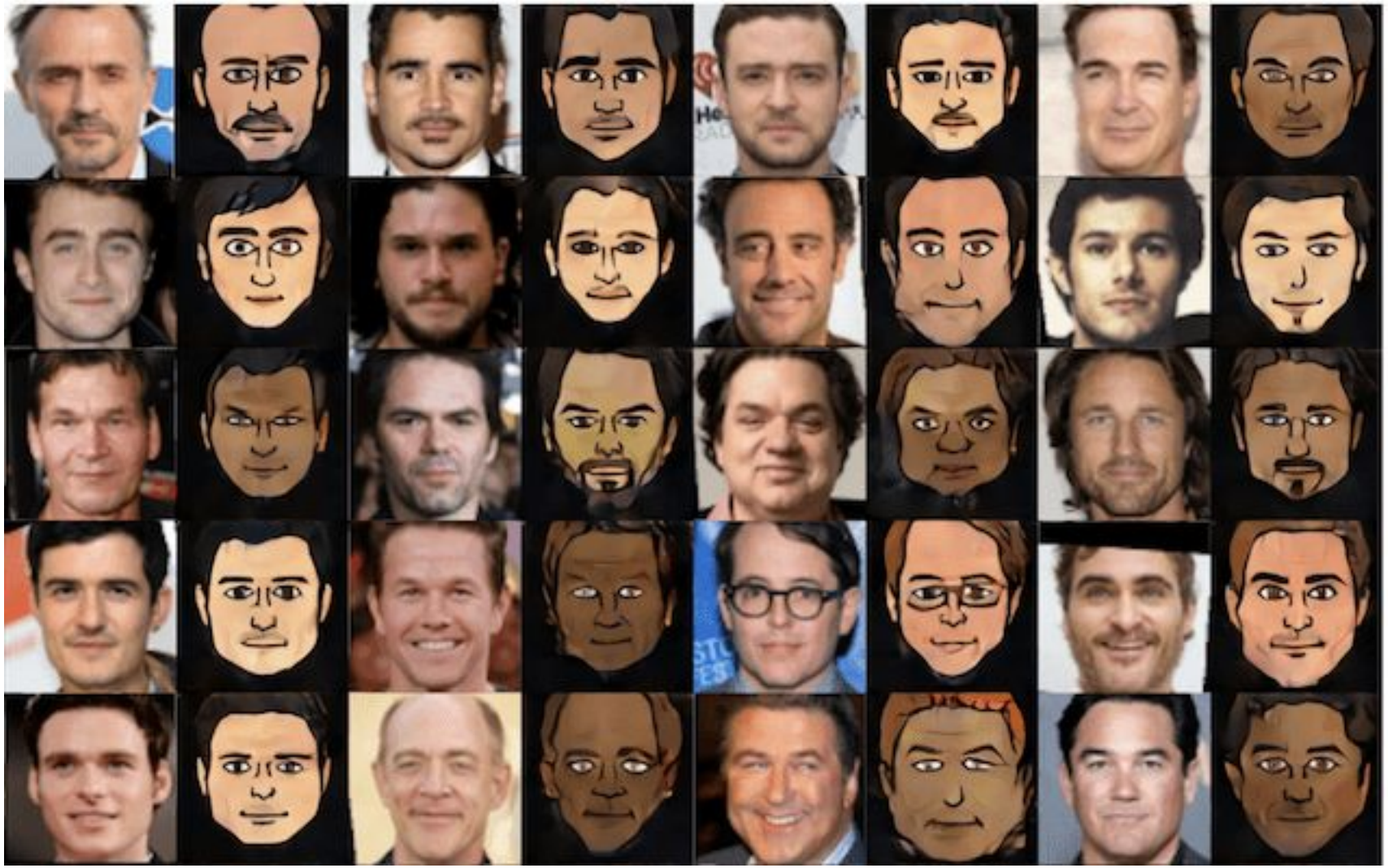
Applications of GANs (Photos to Emojis)



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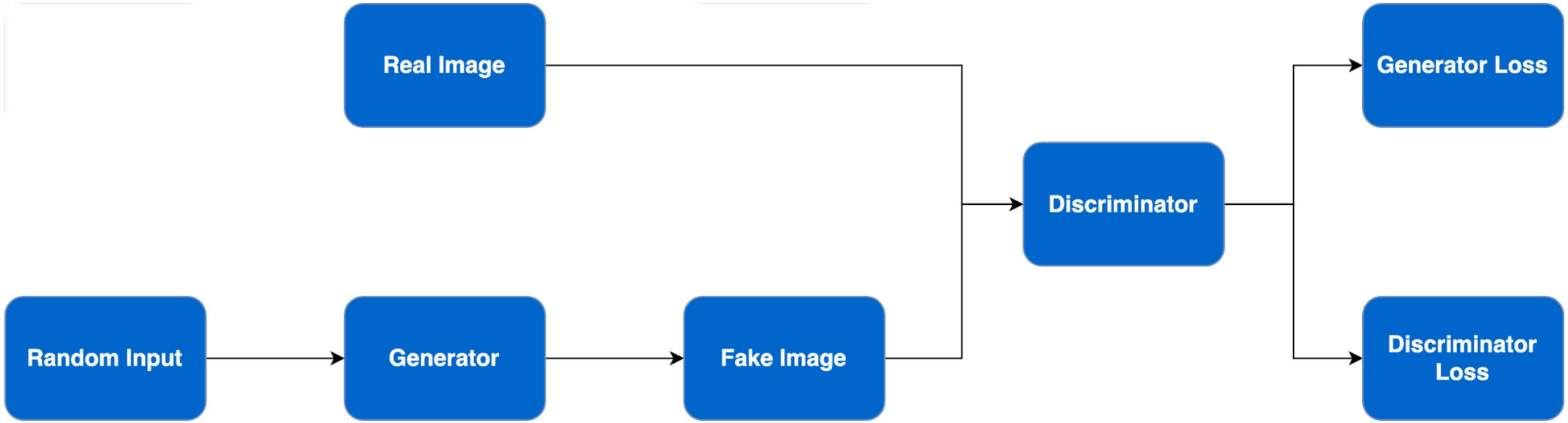
Generator

What are GANs? (Generator)

The **generator** is the first neural network that takes random noise as input and generates new data samples. Its primary role is to create synthetic data that resembles the real data from a training dataset. The generator learns to produce increasingly realistic outputs through adversarial training with the second neural network called the **discriminator**.



What are GANs? (Generator)

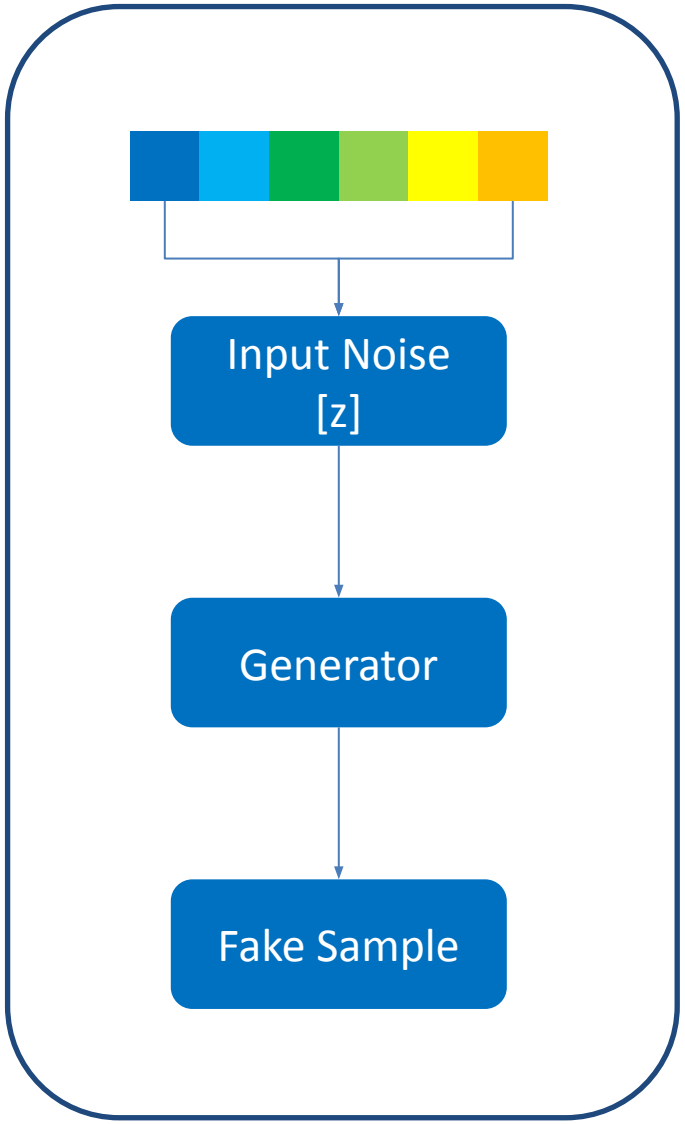
- **Input:** Receives random noise or latent vectors as input, typically sampled from a normal distribution.
- **Output:** Generates synthetic data samples, such as images, audio, or text, that aim to resemble the real data.
- **Objective:** Trick the discriminator into classifying its outputs as real data.
- **Training:** Learns to improve its output quality by minimizing the discriminator's ability to distinguish between real and generated data.

GAN Generator

A key part of making new, accurate data in a Generative Adversarial Network (GAN) is the generator model. The generator takes random noise as input and turns it into complex data samples, like text or images. It is often shown as a deep neural network.

During training, the generator's layers of learnable parts capture the training data's underlying patterns. It adjusts its output to produce samples that closely match real data by using backpropagation to fine-tune its parts.

The generator's success lies in its ability to create high-quality, varied samples that can trick the discriminator.

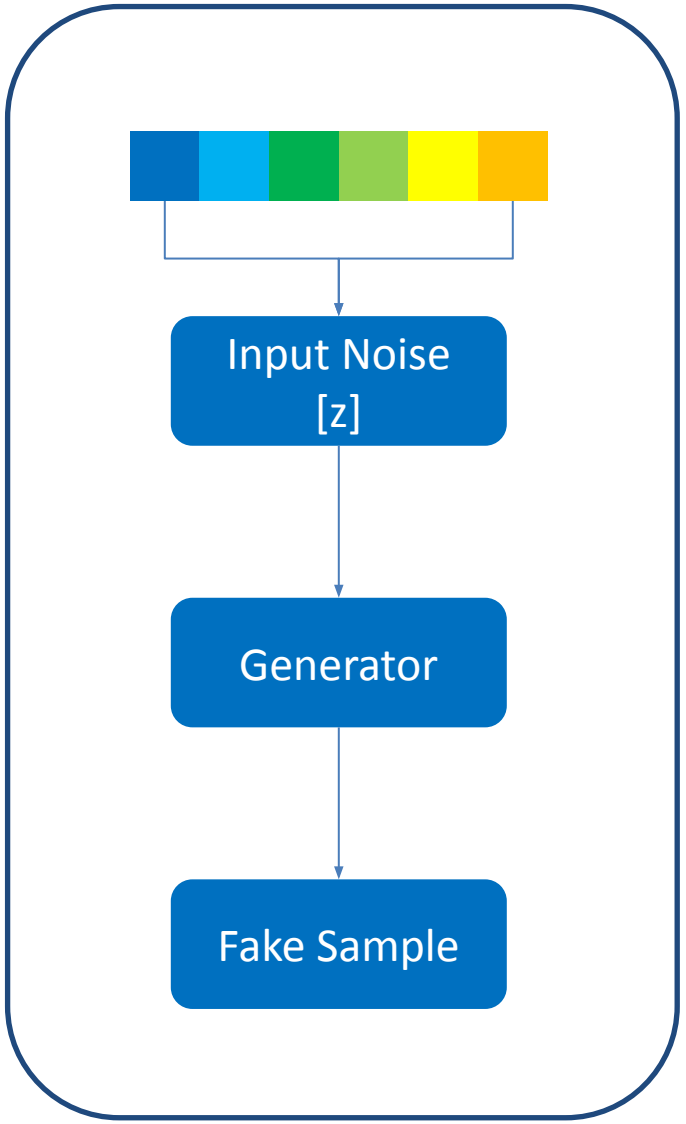


GAN Generator Loss Function

The generator in a GAN aims to create fake samples that appear real enough to deceive the discriminator. It does this by minimizing its loss function, J_G. This loss function is minimized when the log probability is maximized, indicating that the discriminator is very likely to classify the generated samples as real.

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

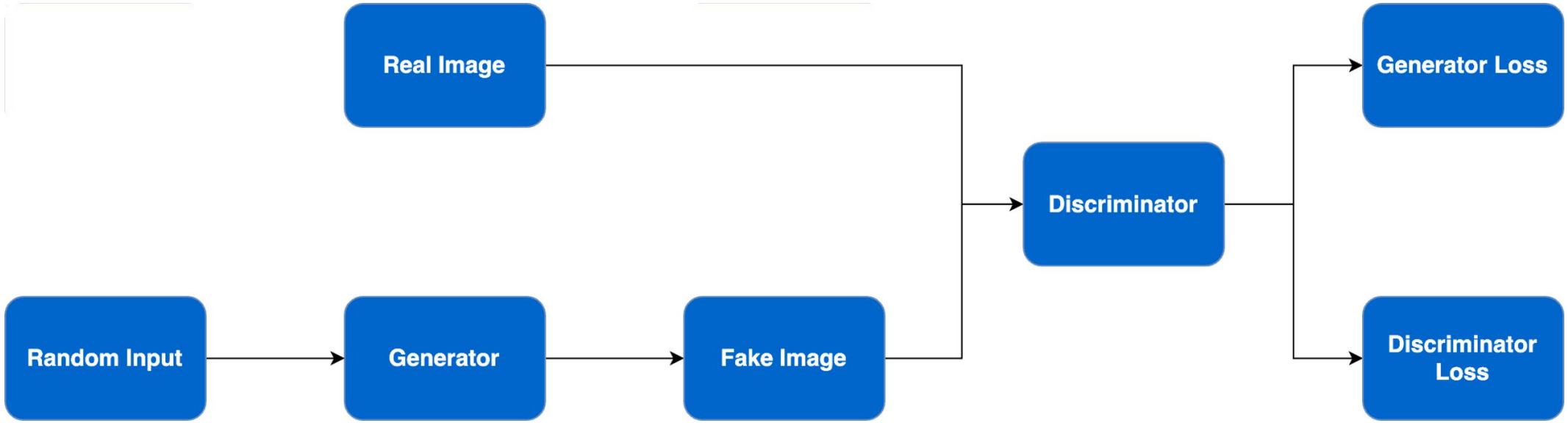
- **J_G**: Represents the generator's loss.
- ***m***: Is the total number of samples.
- ***D***: Denotes the discriminator.
- ***G*(z_i)**: Is the generator's output for the noise input zi.
- ***log***: Signifies the logarithm function.



Discriminator

What are GANs? (Discriminator)

The **discriminator** is the second neural network that acts as a critic. Its primary role is to differentiate between real data samples from a training dataset and synthetic data samples generated by the generator network.



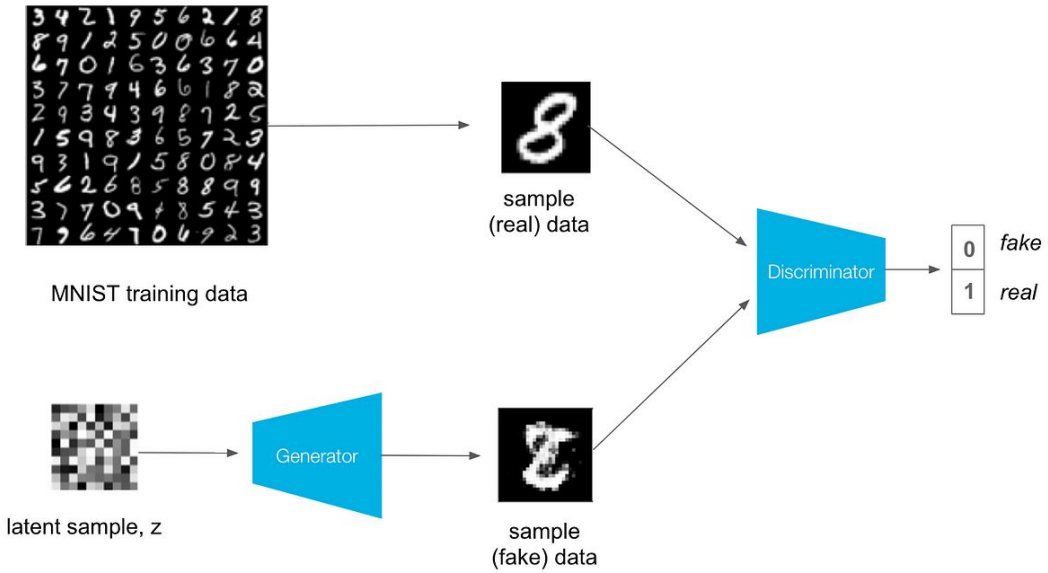
GAN Discriminator

- **Input:** Receives input data samples, which can be either real data from the training dataset or generated data from the generator.
- **Output:** Produces a probability score indicating the likelihood that the input data is real (score close to 1) or generated (score close to 0).
- **Objective:** Classify inputs correctly as real or fake to distinguish between genuine and synthetic data.
- **Training:** Learns to improve its ability to discriminate by optimizing its parameters based on feedback from the generator's performance.

GAN Discriminator cont.

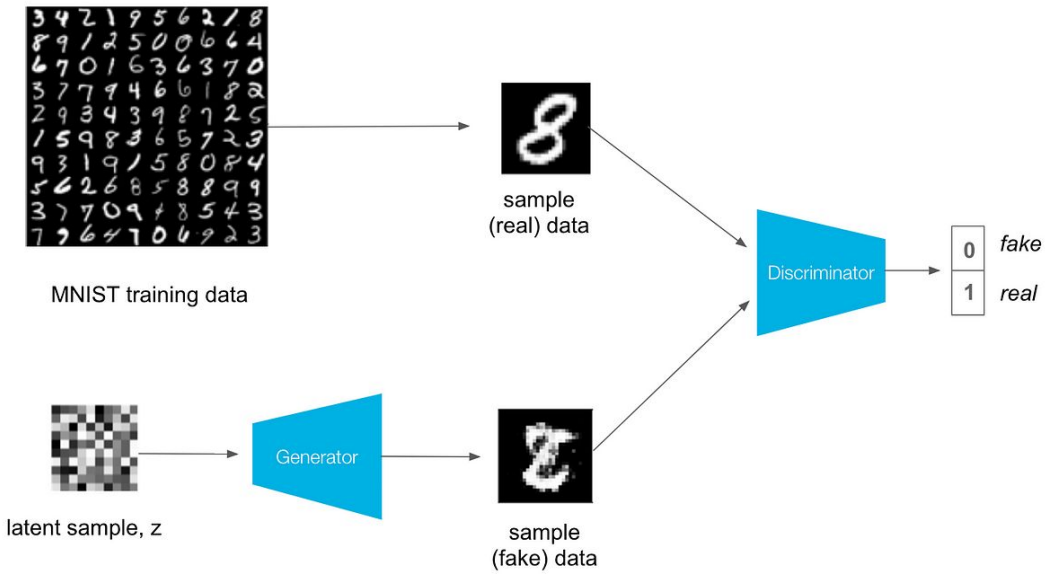
- A **discriminator model** in Generative Adversarial Networks (GANs) is an artificial neural network that distinguishes between generated and real input. It acts as a binary classifier by assessing input samples and assigning a probability of authenticity.

- As it processes data over time, the discriminator becomes adept at distinguishing genuine data from the dataset and synthetic samples generated by the GAN. This iterative process allows the discriminator to refine its parameters and improve its accuracy.



GAN Discriminator cont.

- When processing images, the **discriminator** usually includes convolutional layers or relevant structures. Adversarial training aims to improve its accuracy in distinguishing fake from genuine samples. As the generator and discriminator interact, the discriminator becomes more effective, enhancing the GAN's ability to create realistic synthetic data.

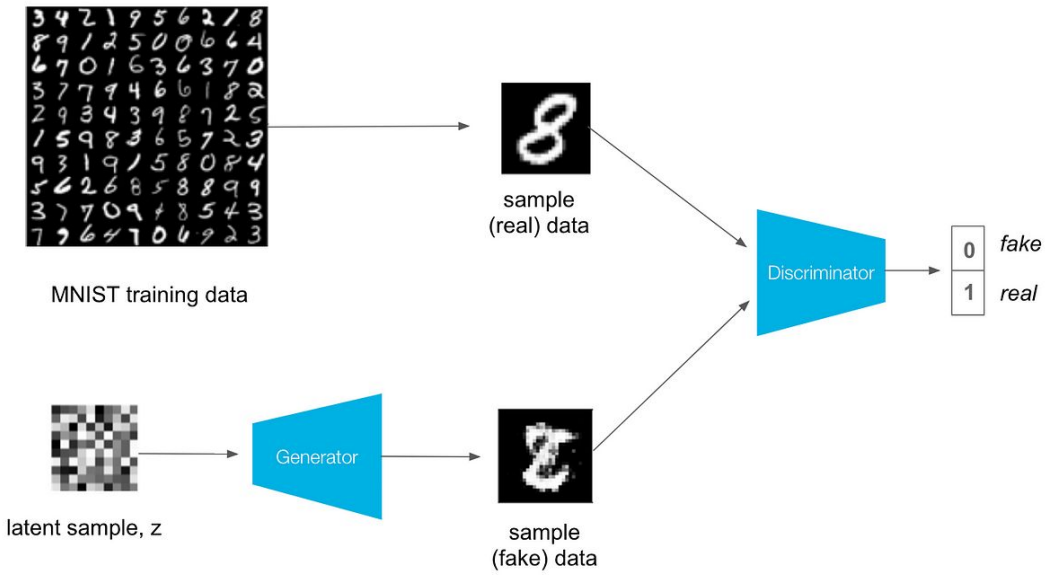


GAN Discriminator Loss Function

The discriminator minimizes its loss by reducing the negative log likelihood of correctly classifying both generated and real samples. This loss is defined as:

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

- **log $D(x_i)$:** Represents the log likelihood of the discriminator correctly categorizing real data x_i.
- **log$(1-D(G(z_i)))$:** Represents the log likelihood of the discriminator correctly categorizing generated samples $G(z_i)$ as fake.



How does it work?

How does GAN work?

1. **Initialization:** Two neural networks are set up:
   - Generator (G).
   - Discriminator (D).
2. **Generating Data:**
   - **Generator (G):** Creates new data, such as images or text, that closely resembles real data. It starts with a random noise vector and uses learned patterns to transform it into a new sample.

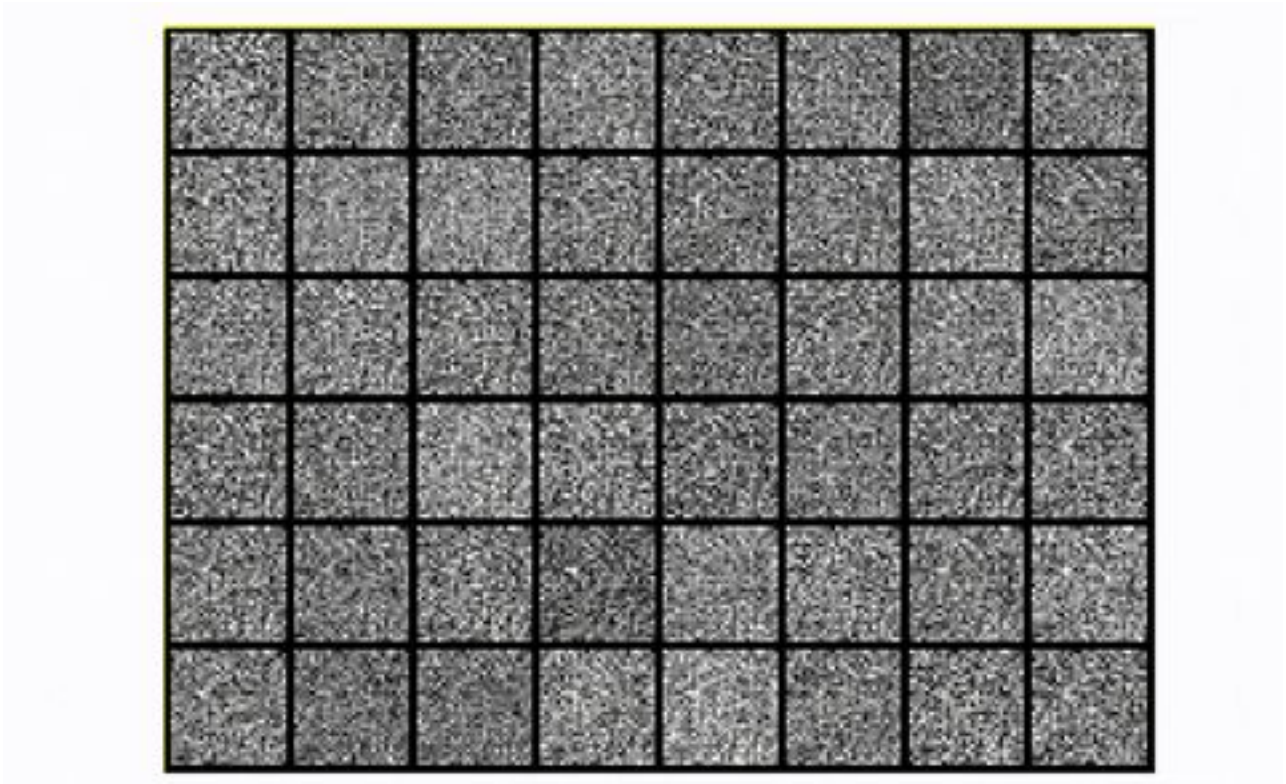
How does GAN work?

3. **Discriminating Real vs. Fake:**
    - **Discriminator (D):** Acts as a critic. It receives two types of inputs:
        - Real data samples from a training dataset.
        - Data samples generated by G.
        - D's task is to distinguish between these inputs and assign a probability score (0 to 1) indicating whether each input is real or generated by G.
4. **Learning Process:**
    - **Adversarial Feedback:** If D correctly identifies real data as real (score near 1) and generated data as fake (score near 0), both G and D receive minor rewards.
    - However, the aim is continual improvement. G seeks to progressively deceive D, while D aims to maintain accurate discrimination.

How does GAN work? cont.

5. **Improving the Generator:**
   - When D incorrectly labels G's output as real (high score), G receives a significant reward for fooling D. This feedback guides G to refine its data generation process, making outputs more realistic.
6. **Adapting the Discriminator:**
   - Conversely, if D correctly identifies G's output as fake (low score), D strengthens its discrimination abilities without a reward for G.
7. **Continuous Refinement:**
   - This iterative process of competition and feedback between G and D continues, refining both networks over time to generate increasingly realistic data.

GANs in action



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Thank you!

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