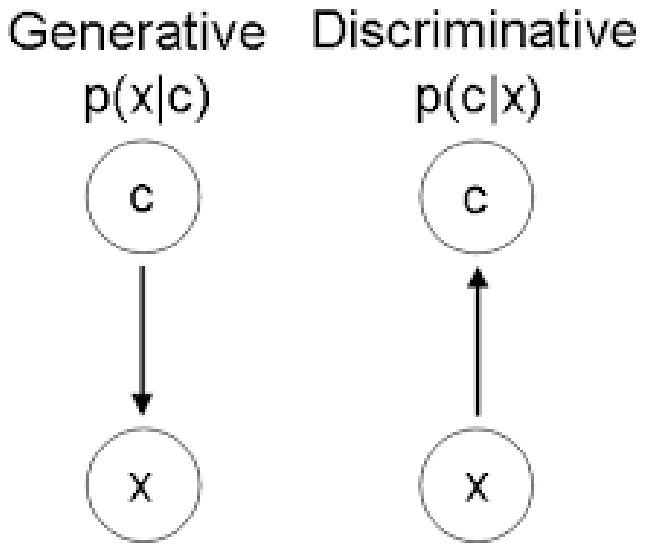
Generative Adversarial Network (GAN)

Two forms of Machine Learning

- **Discriminative**
- **Generative**



Generative Adversarial Network

Counterfeiter

Fraud Detector

Generative Adversarial Network

Counterfeiter

Generator

Fraud Detector

Discriminator

Generative Adversarial Network

Generator generates fake samples as real as possible and tries to fool the **Discriminator**

Discriminator tries to detect the fake samples generated by the **Generator**

Generative Adversarial Network

Generator

Discriminator

They are trained in an adversarial setting to master each other's task.

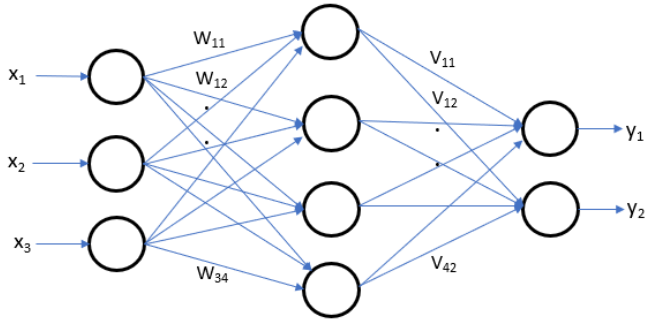
Magic of GANs….

- Images generated using StyleGAN- a GAN variant
- These people don’t exist in real!!!!!!
- Image from Paper ‘*A Style-Based Generator Architecture for Generative Adversarial Networks*’

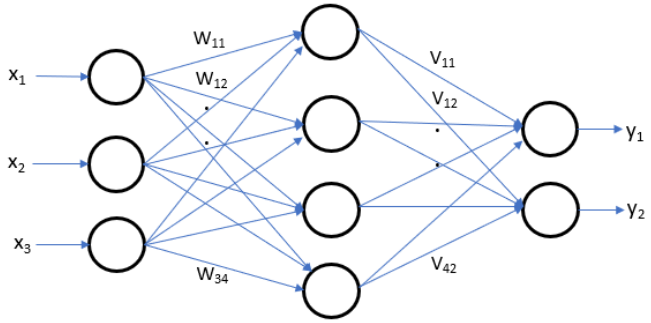
Karras, Tero et al. “A Style-Based Generator Architecture for Generative Adversarial Networks.” *2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)* (2019): 4396-4405.

GAN – both the generator and Discriminator are neural network

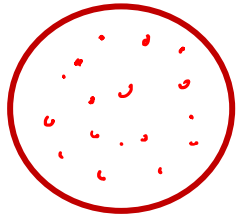
Generator



Discriminator



GAN – both the generator and Discriminator are neural network



D

$x \sim D$

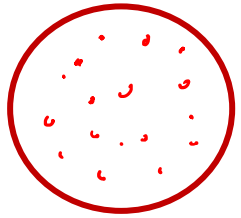
Real Data Distribution

Z

$z \sim Z$

Random Sample

GAN – both the generator and Discriminator are neural network



D

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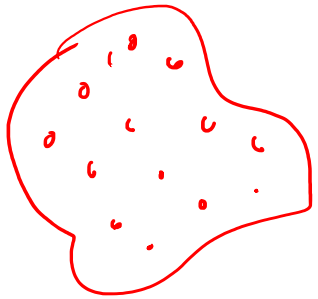
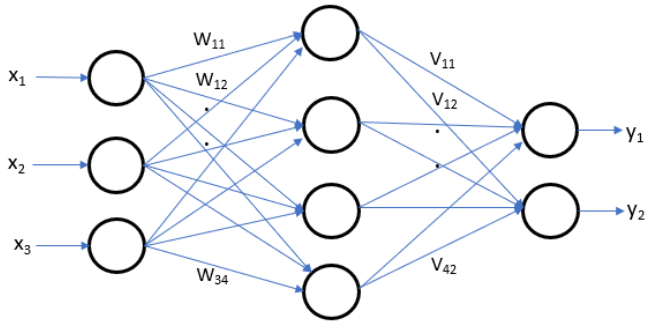
Real Data Distribution

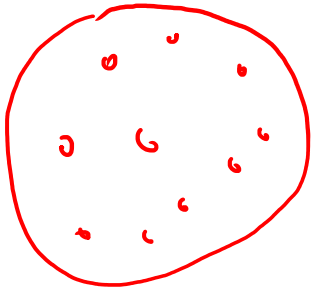


Z

$z \sim Z$



$G(z)$



D'

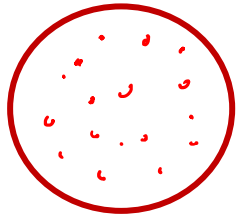
$\mathrm{G(z)} \sim D'$

$D \cong D'$

Random Sample

Generator

GAN – both the generator and Discriminator are neural network



D

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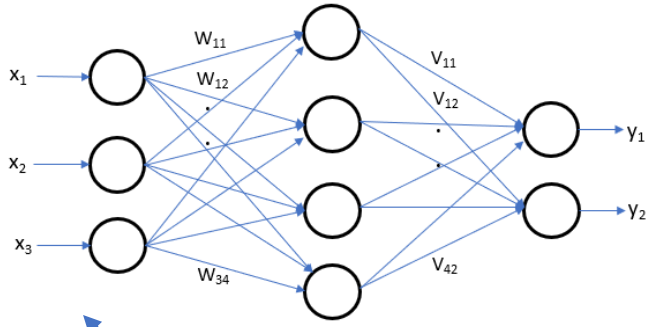
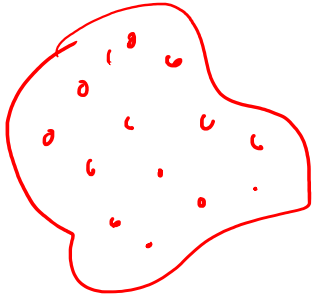
Real Data Distribution



Discriminator

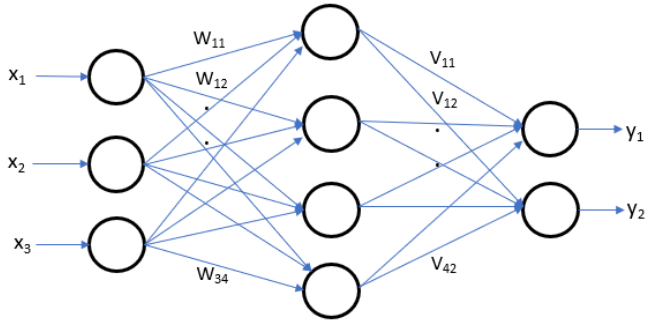
Fake/Real



Z

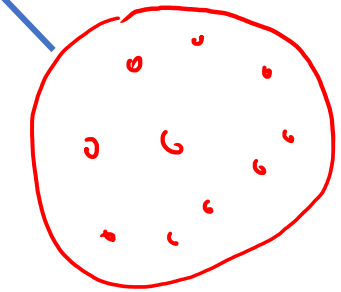
$z \sim Z$

Random Sample



Generator

$G(z)$



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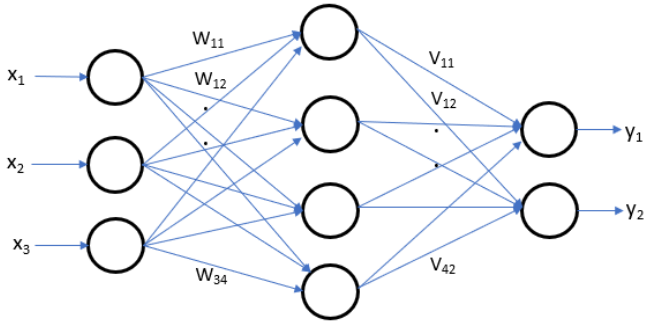
$D \cong D'$

GAN – both the generator and Discriminator are neural network

$$x \sim D$$

Real Data Distribution



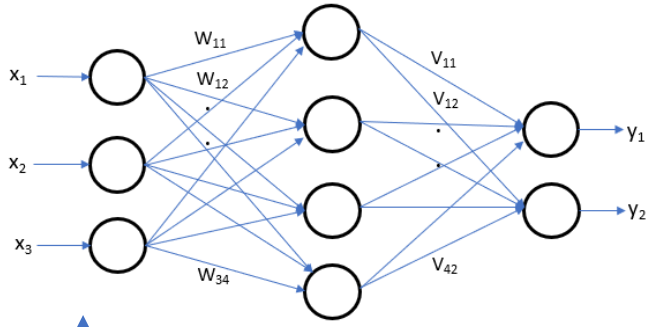
Discriminator

Real

GAN – both the generator and Discriminator are neural network

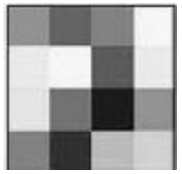
$$x \sim D$$

Real Data Distribution



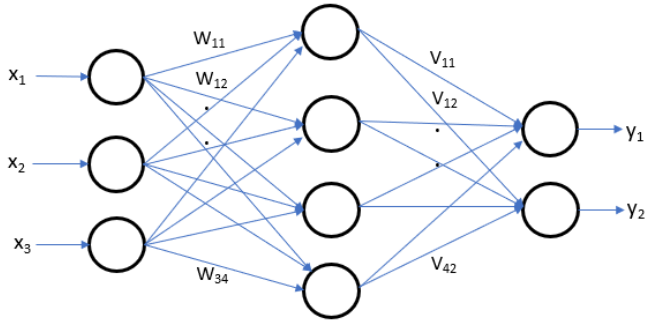
Discriminator

Fake

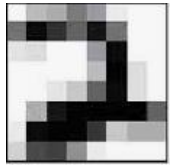


$$z \sim Z$$

Random Sample



Generator



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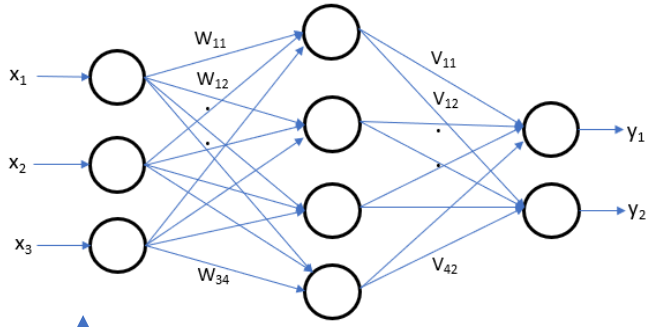
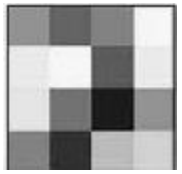
$$x \sim D$$

Real Data Distribution



Discriminator

Fake



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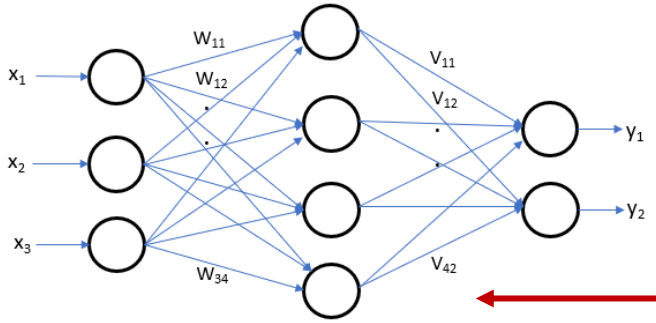
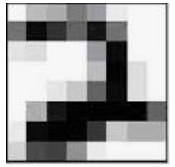




Random Sample

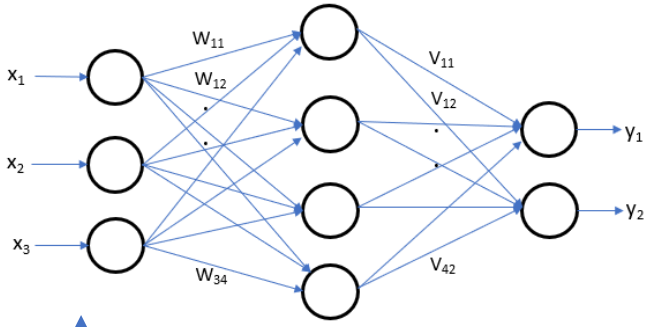
Generator

Error

GAN – both the generator and Discriminator are neural network

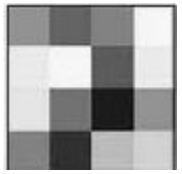
$$x \sim D$$

Real Data Distribution



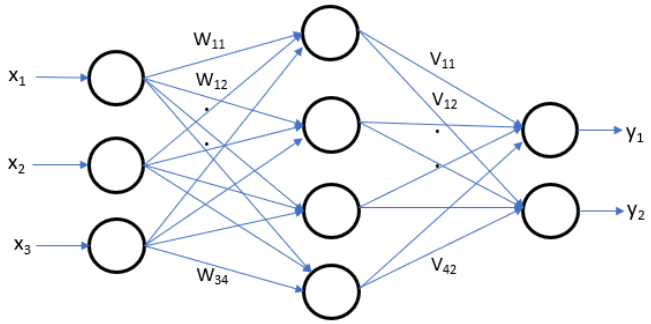
Discriminator

Fake



$$z \sim Z$$

Random Sample



Generator

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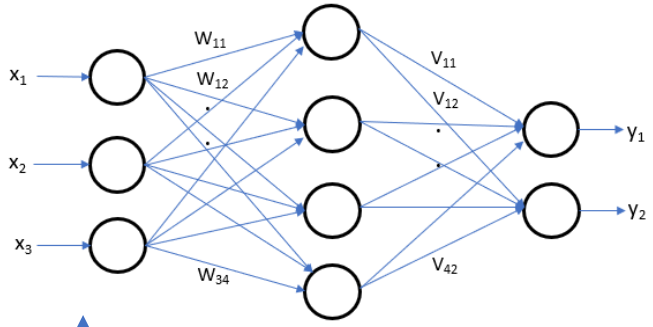
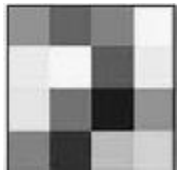
$$x \sim D$$

Real Data Distribution



Discriminator

Fake



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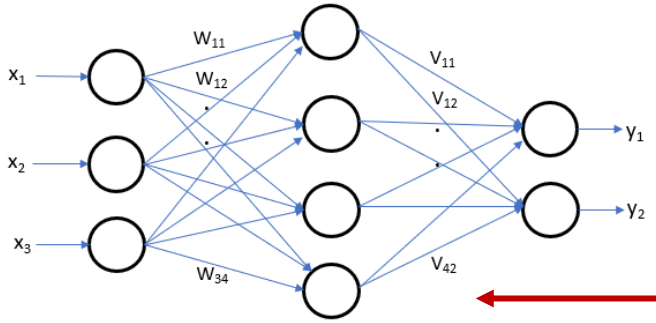

Random Sample

Generator

Error

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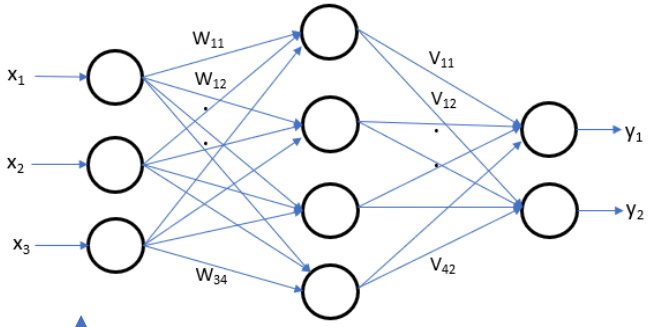
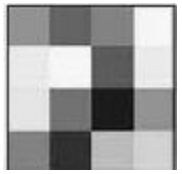
$$x \sim D$$

Real Data Distribution



Discriminator

Real



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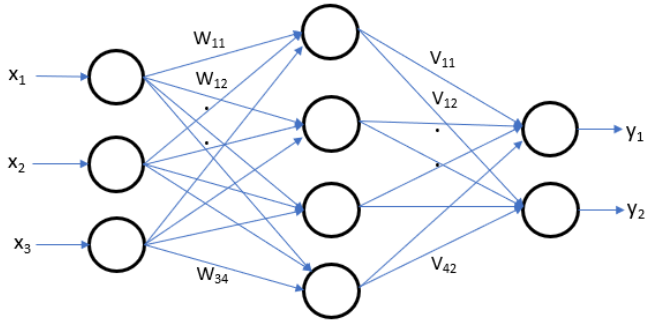
Random Sample



Generator

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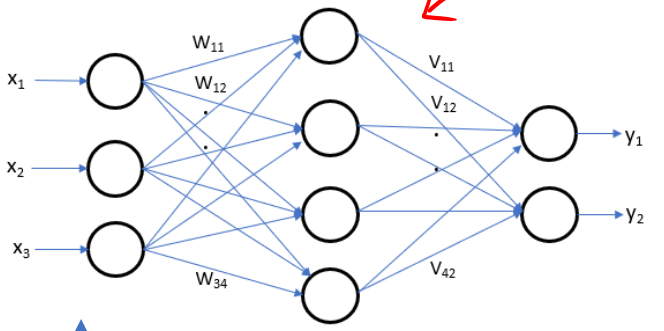
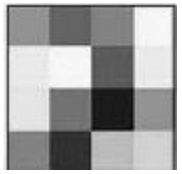
Real Data Distribution



Discriminator

Error

Real



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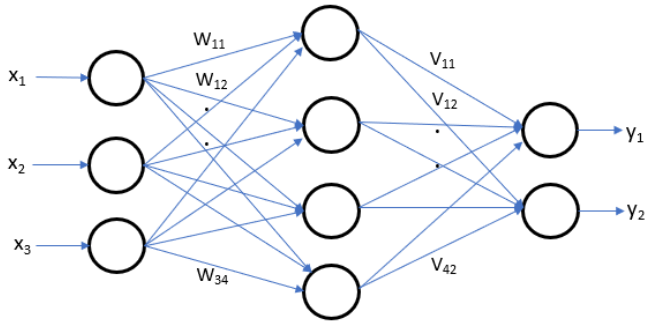

Random Sample

Generator

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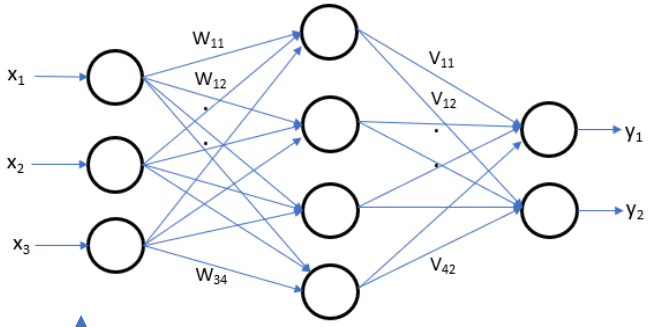
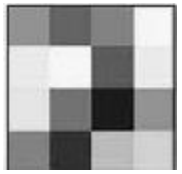
Real Data Distribution

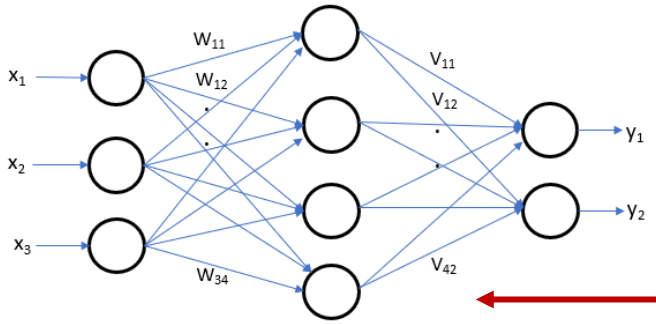


Discriminator

Fake



$$z \sim Z$$



Random Sample

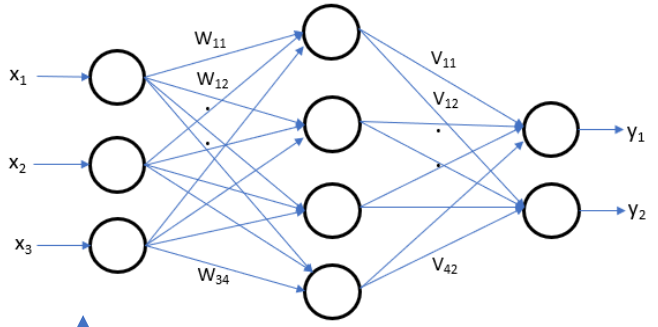
Generator

Error

GAN – both the generator and Discriminator are neural network

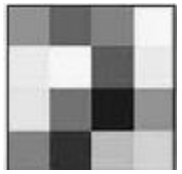
$$x \sim D$$

Real Data Distribution



Discriminator

Fake



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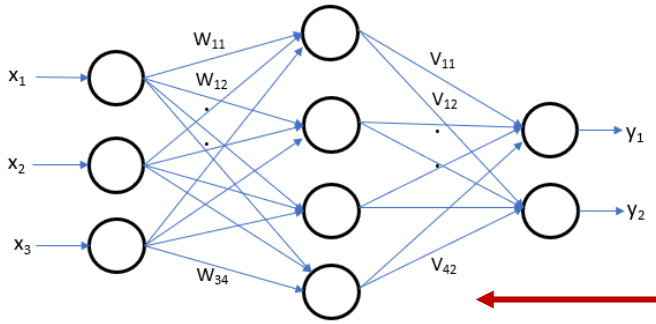
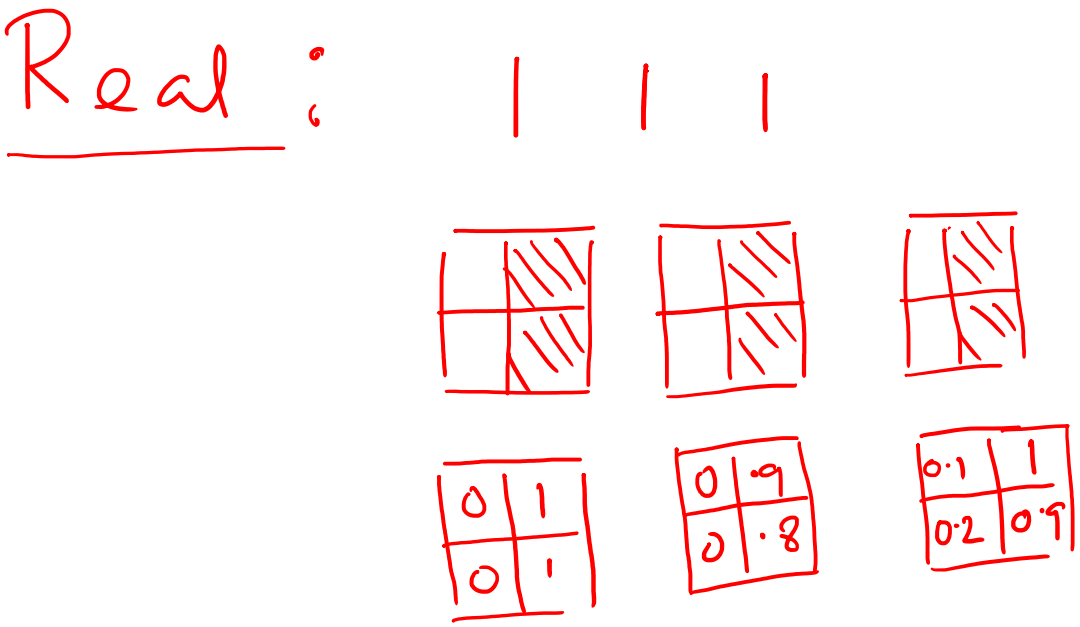


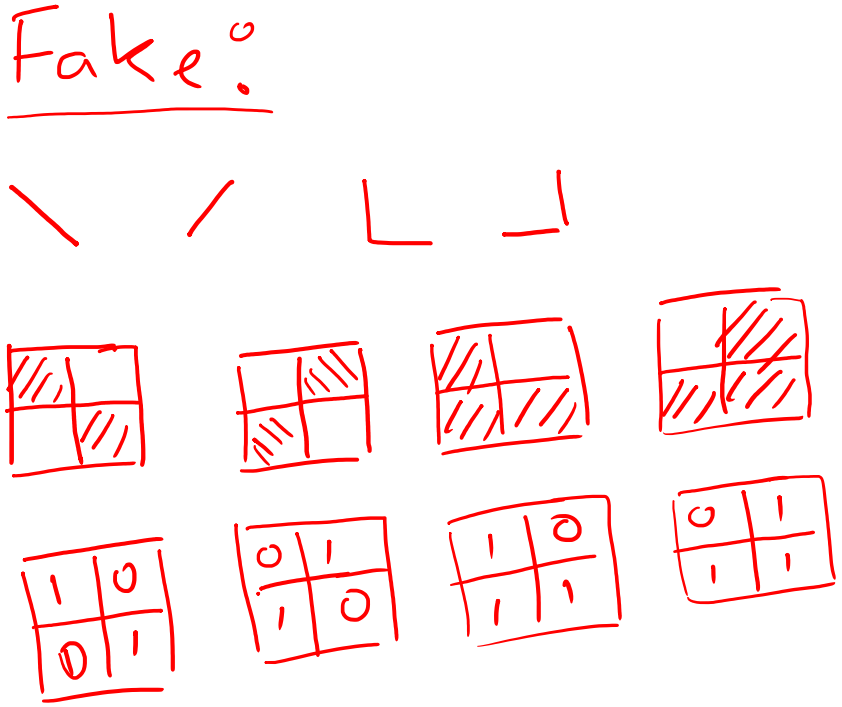
Random Sample

Generator

Error

GAN – A toy Example





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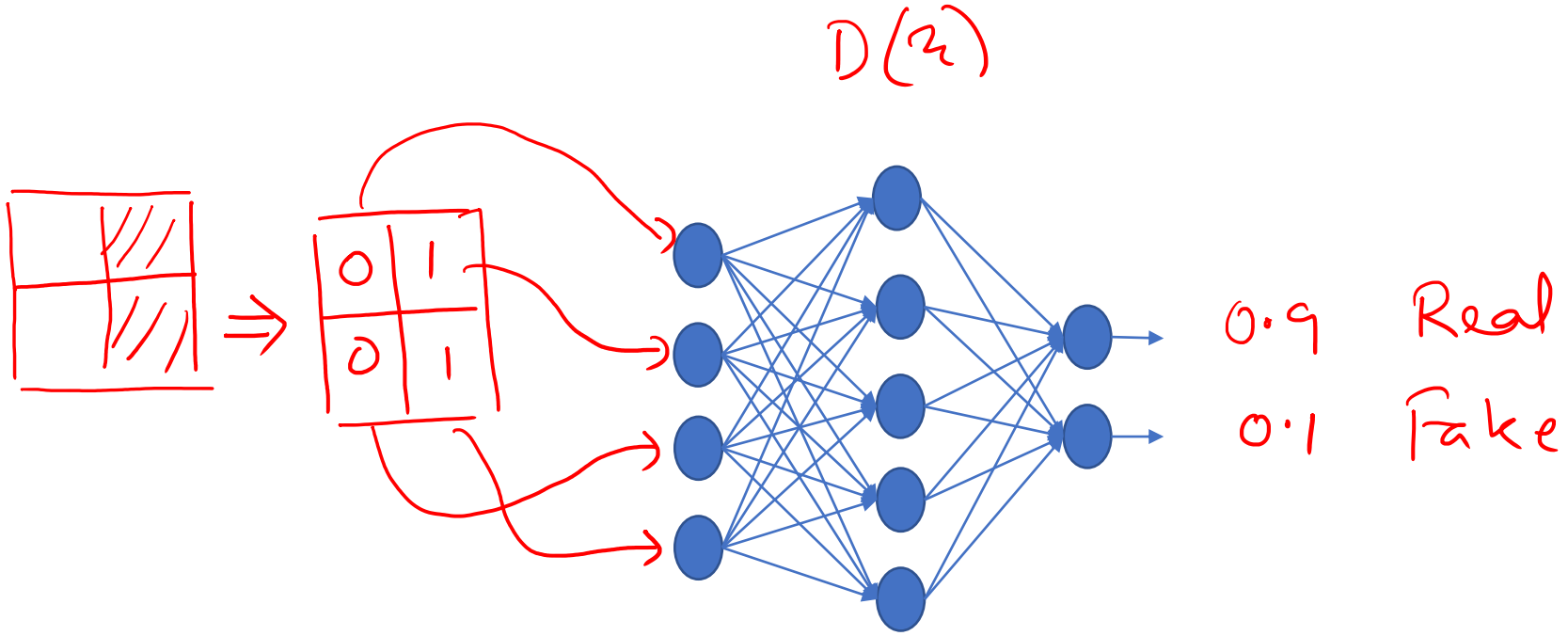

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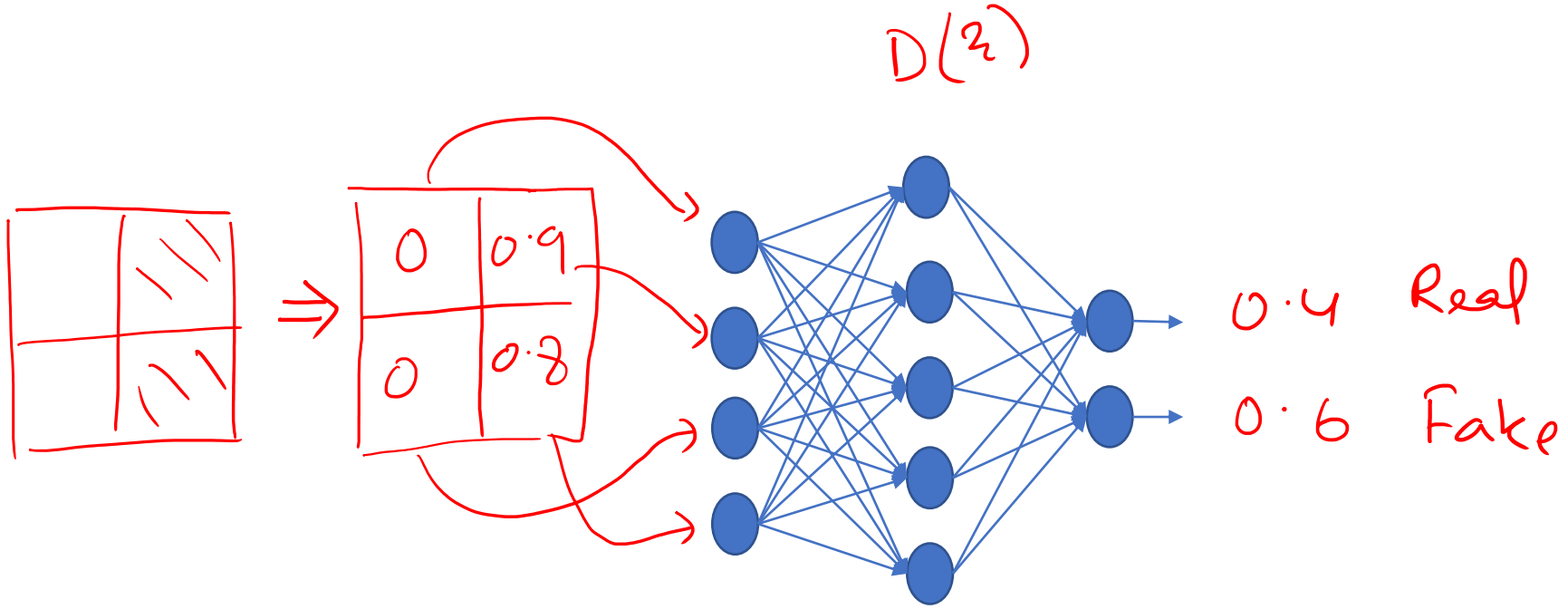

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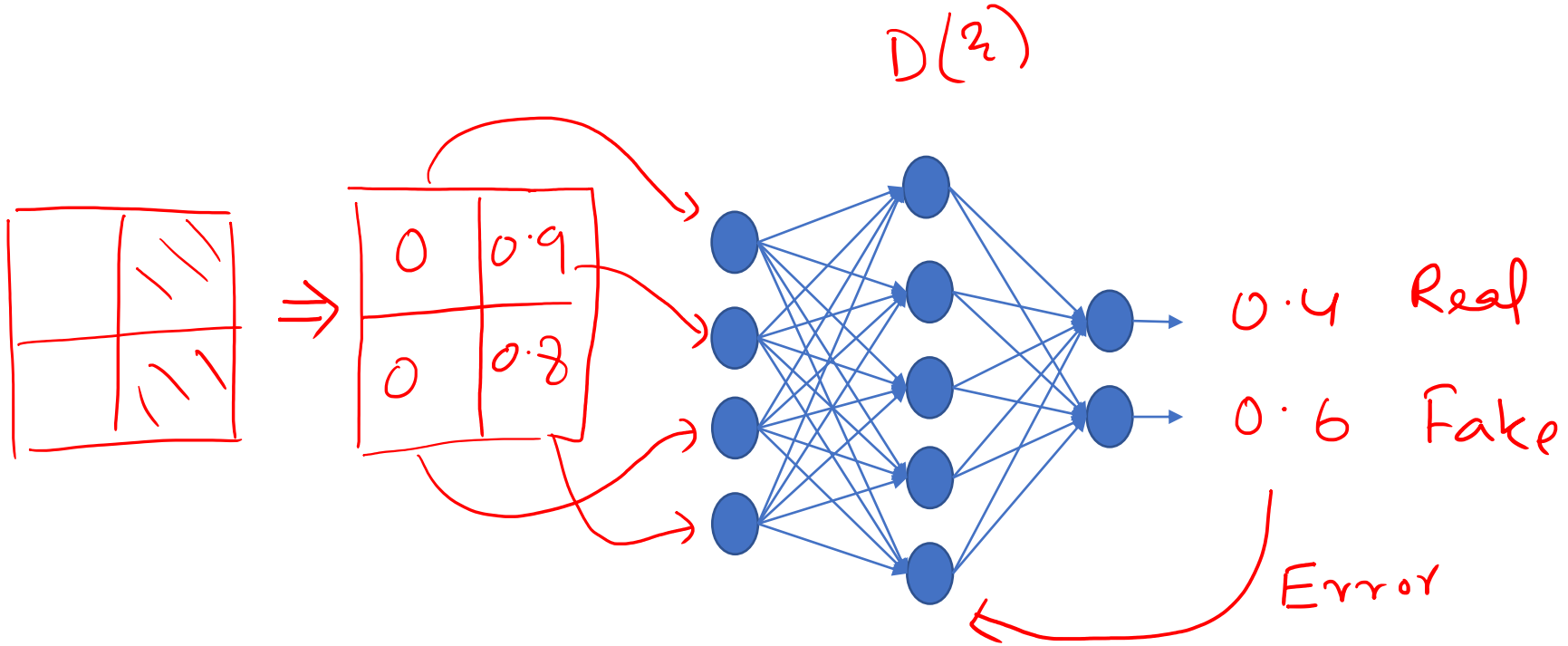

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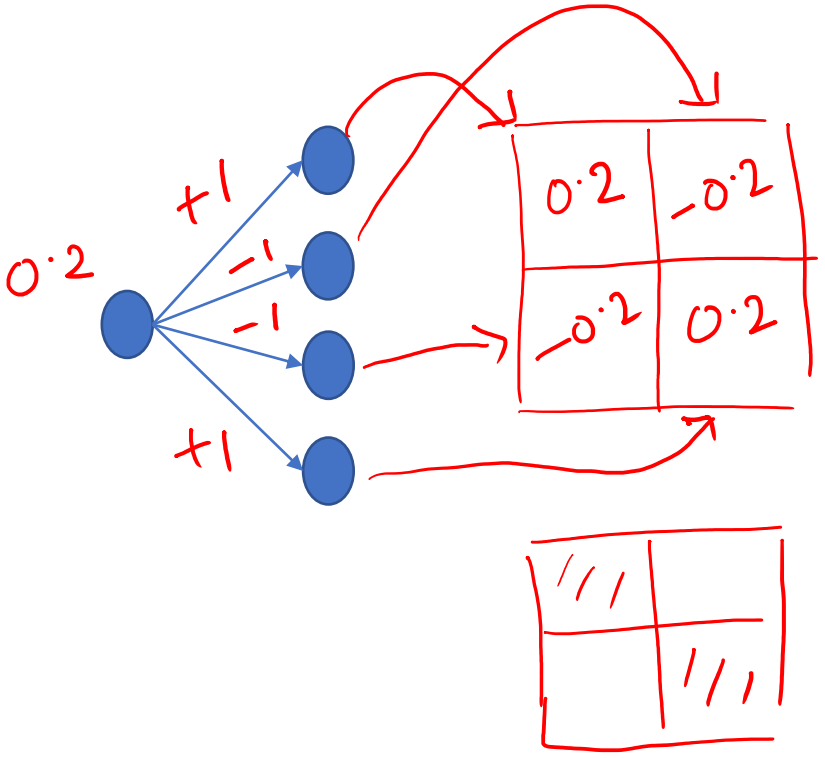

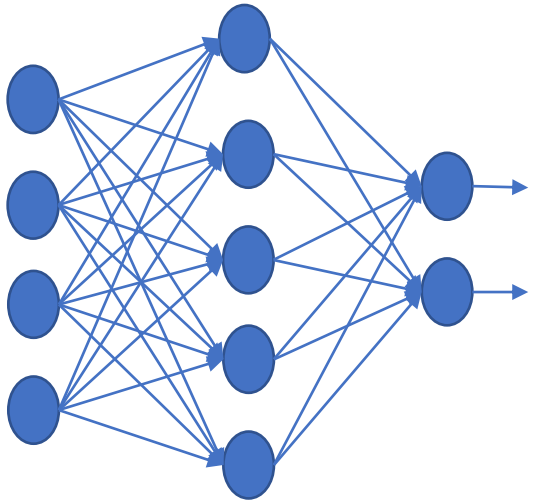

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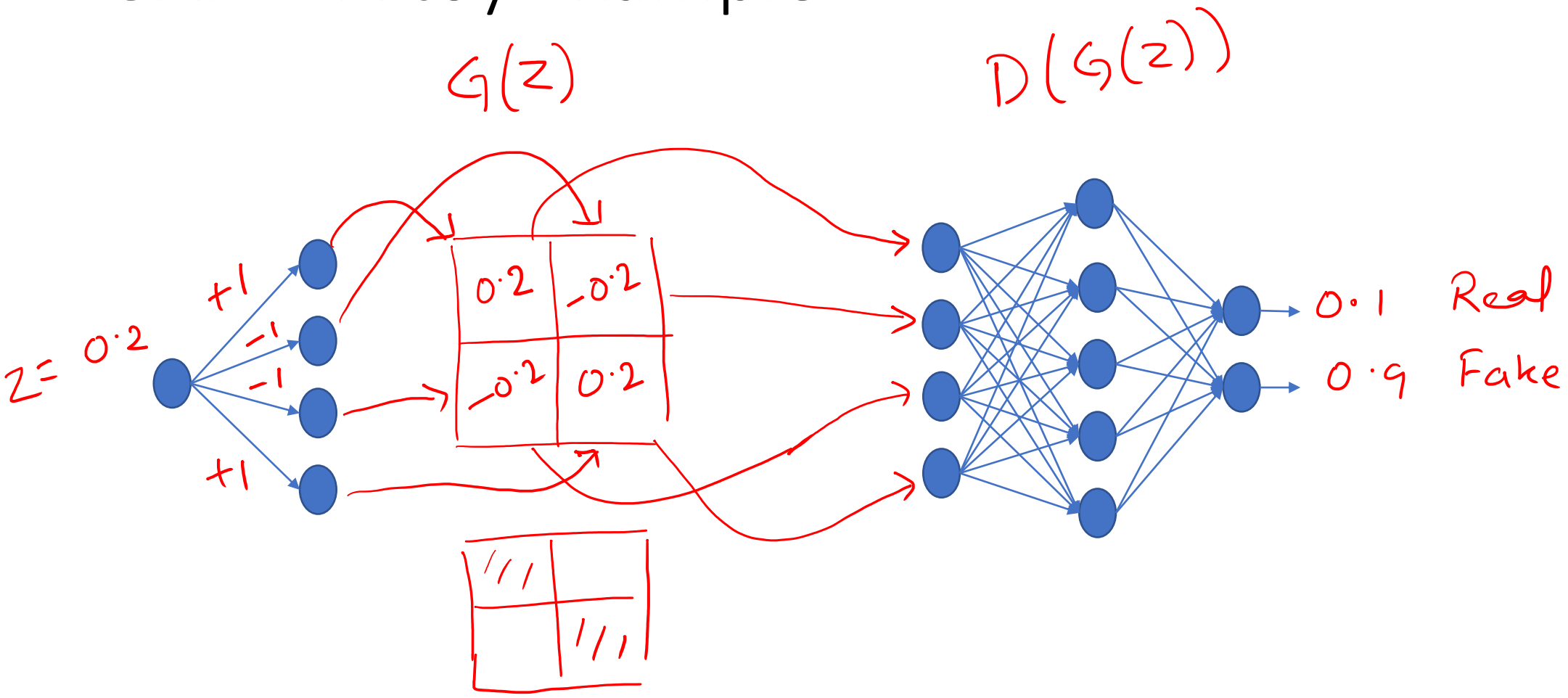
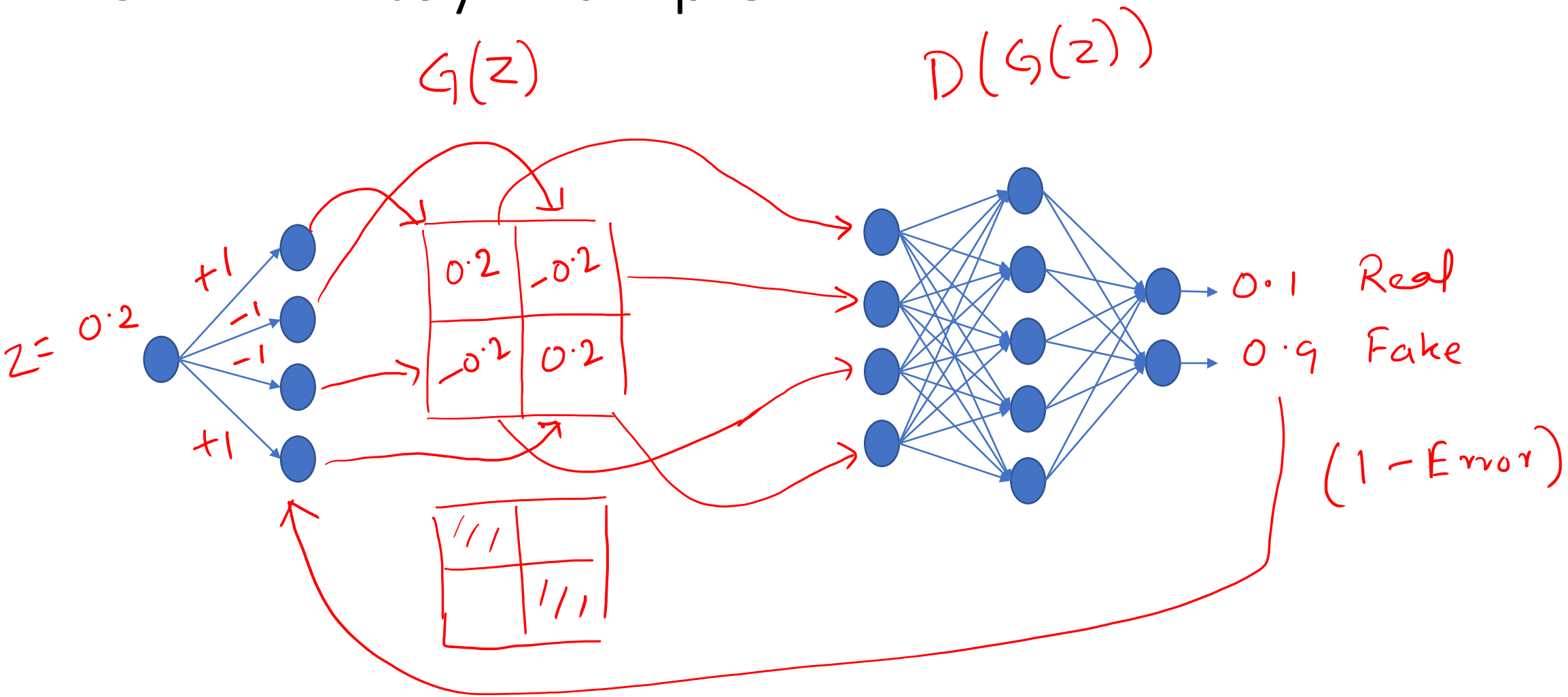


GAN – A toy Example



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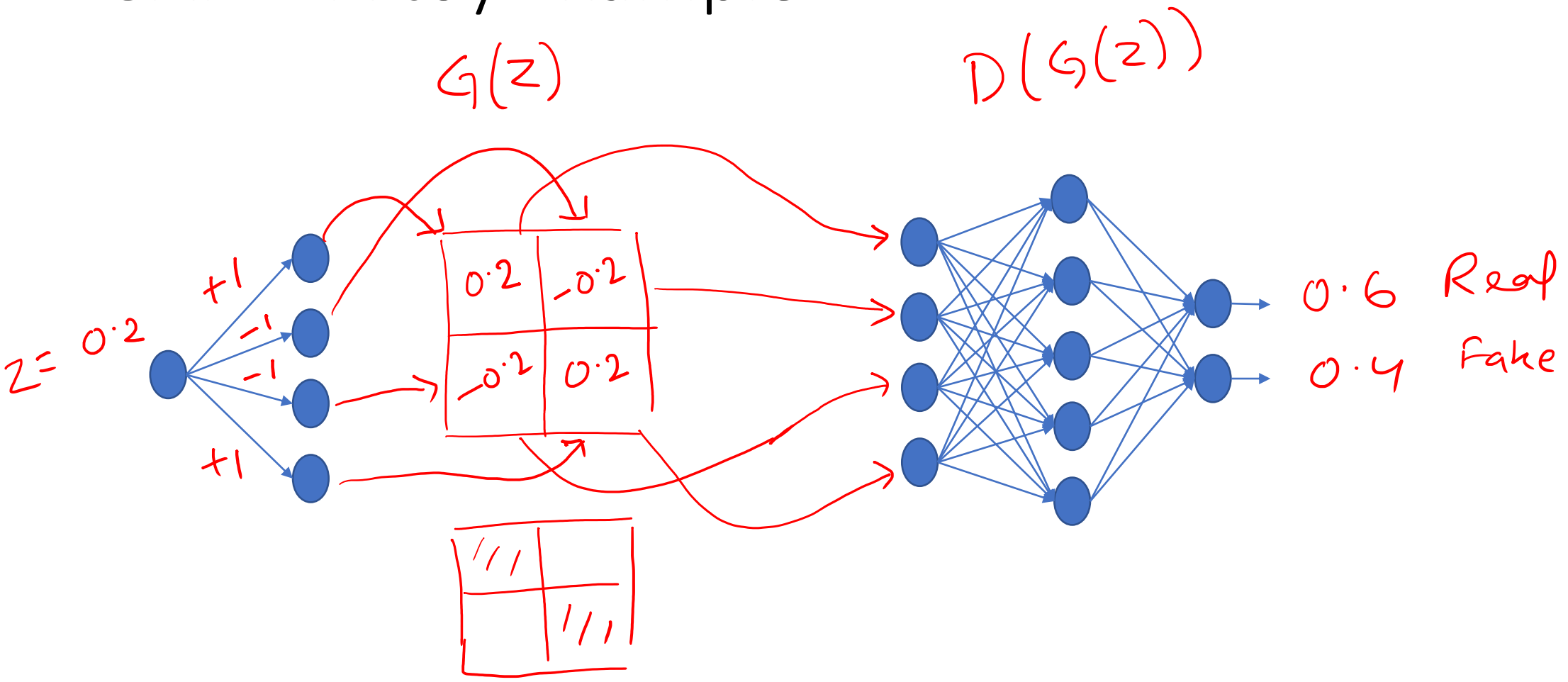
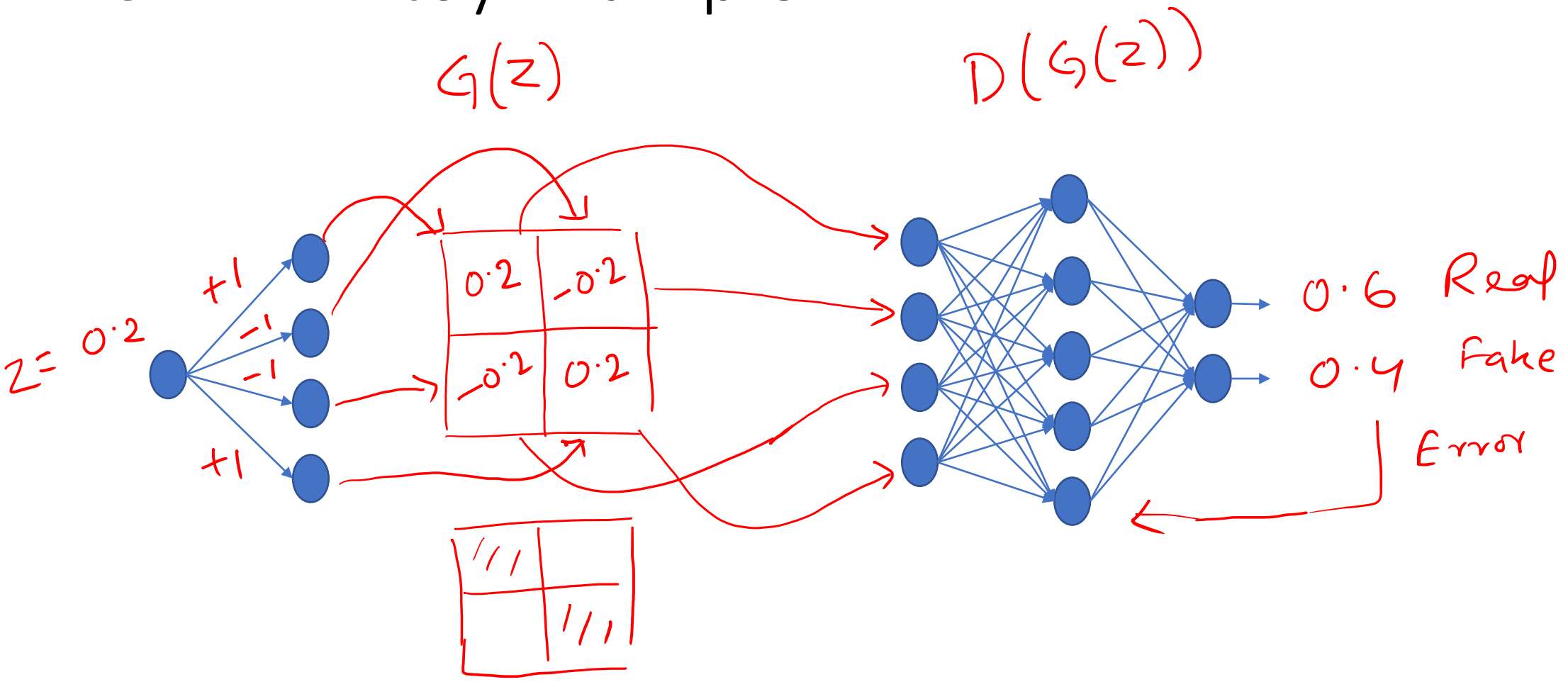
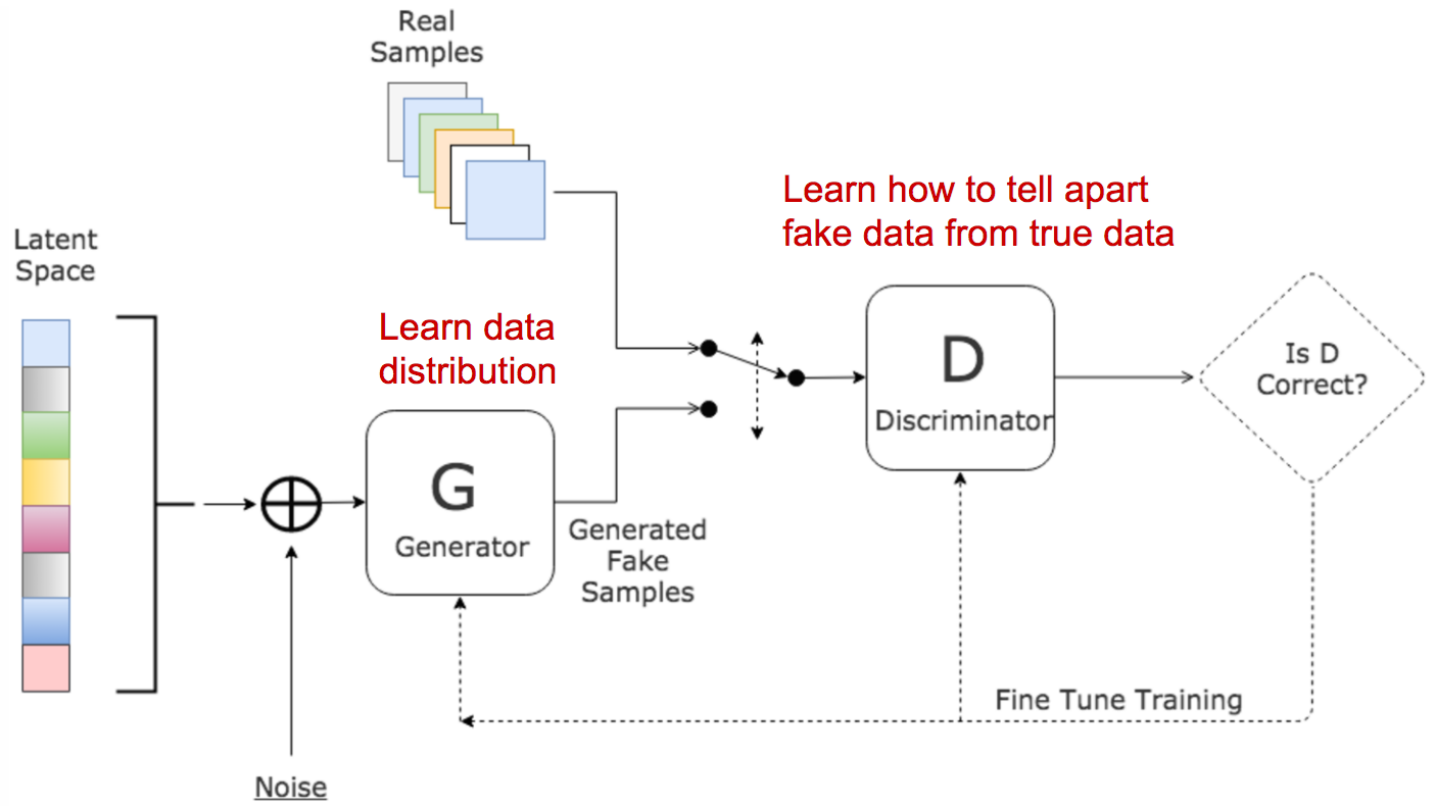


GAN – A toy Example



GAN Framework



- Generator + Discriminator = **GAN**
- The latent vector belongs to some random distribution (Uniform/Gaussian)
- Both the generator and discriminator network parameters are updated during training

GAN – Loss Function

- Discriminator's decision over real data should be accurate
  - **Maximize** $\mathbb{E}_{x \sim p_r(x)}[\log D(x)]$
- Discriminator's decision over generated data should be considered fake
  - **Maximize** $\mathbb{E}_{z \sim p_z(z)}[\log(1 - D(G(z)))]$
- Generator is trained to increase the chances of D producing a high probability for a fake sample

$$\min_G \max_D L(D, G) = \mathbb{E}_{x \sim p_r(x)}[\log D(x)] + \mathbb{E}_{z \sim p_z(z)}[\log(1 - D(G(z)))]$$