Generative Adversarial Networks

A CS590 Class

Generative models
- What
- Why

GAN : A two-player game
- The players
- The game

GAN : An analogy
- Counterfeiter vs. Cop
- Who wins ?

Losses and Problems
- Minimax loss
- Training issues

DCGAN : An example
- Architecture and contributions
- A note on Deconvolution

Closing it with codes
- Hands-on (in PyTorch)
- References

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What are generative models? What's the need?

Create new data instances that look like the training data !

Attribute2Font

Anime face generation

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More applications!

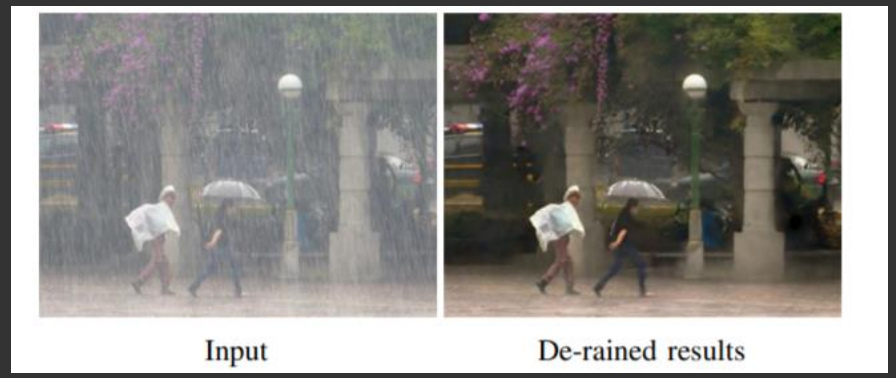

Image de-raining

Text2Image

Image super-resolution

Face completion

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“*GAN is a two-player minimax game*”

Let’s first familiarize ourselves with the players and their purpose.....

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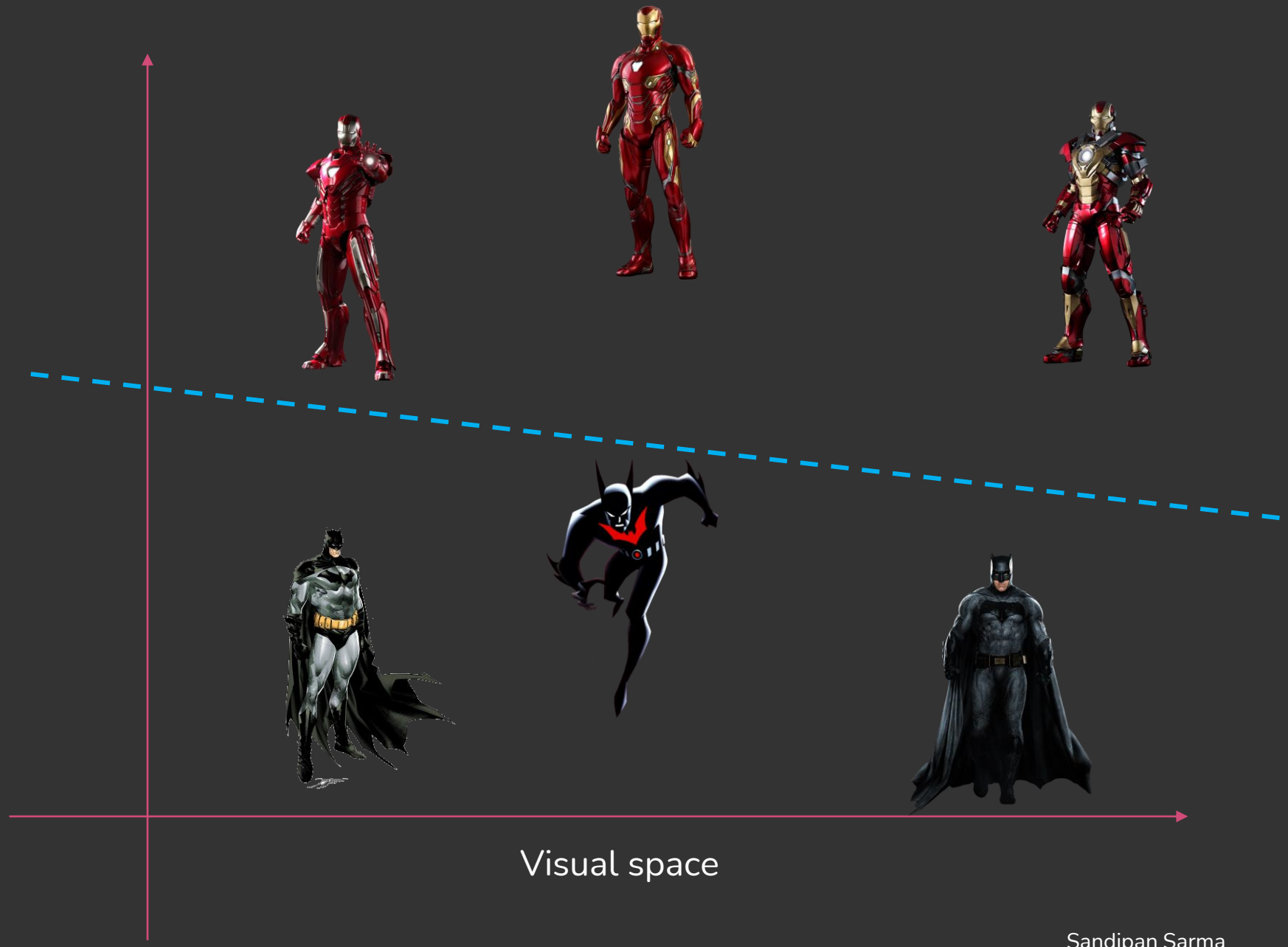
Purpose of Player A

- Look at different **Batsuits** and **Ironman armors** (y) and corresponding visual images (x)
- Mathematically, learn P(y|x)
- Learn difference between Ironman and Batman

- Hence, player name:

Discriminative model



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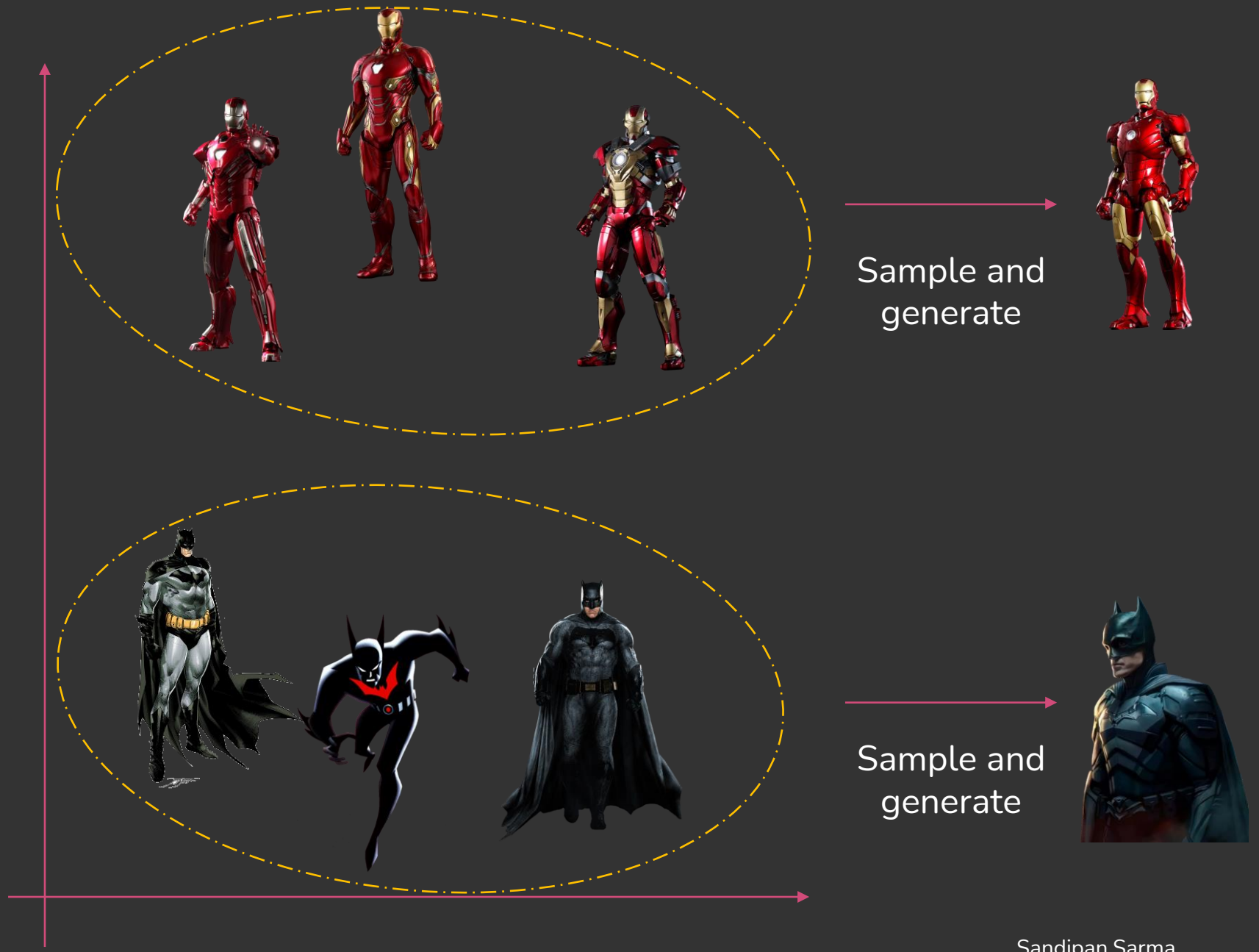
Purpose of Player B

- Look at different **Batsuits** and **Ironman armors** (y) and corresponding visual images (x)
- Mathematically, learn P(x,y)
- Learn to imitate data distribution of Ironman and Batman
- Generate new suits from each distribution

- Hence, player name:

Generative model



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Counterfeiting currency bills

Tries to generate real-like counterfeit bills

Tries to catch fake bills, but incurs penalty if he fails

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An amateur counterfeiter gets caught

Initial attempt at counterfeiting bills

Fake bills easily identified

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Counterfeiter learns from previous mistakes and successfully fools the cop

Improvement to generate even better bills

Cannot spot the difference between real and fake note this time, so incurs a loss (penalty)

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A better cop can still identify the fake bills

Improvement to generate even better bills

Understands discrimination between real and fake notes in greater detail

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Further improvement by counterfieter

Achieving expertise at counterfeiting

Looks almost real !

Winner?

(GENERATOR) ⟷ **(DISCRIMINATOR)**

Both improve themselves through each other's feedback

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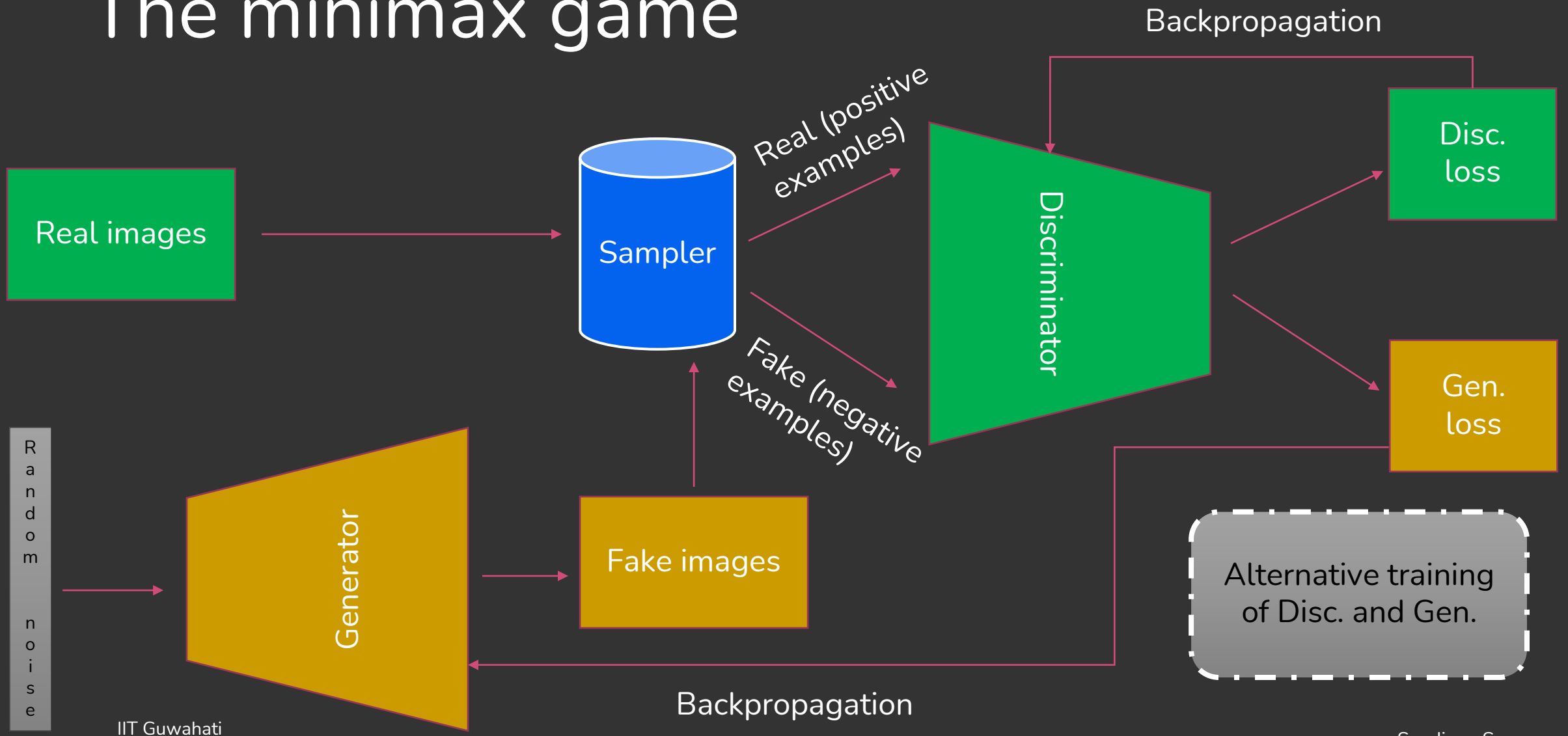
The minimax game



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Why differentiability?

- Most machine learning algorithms formulated as convex optimization problems
- Gradient computations
- Differentiable functions don’t have sudden jerks – can be interpolated/extrapolated to get predicted value reasonably close to actual value

Loss functions

Minimax loss (original paper on GAN [7]):

$$E_x[log(D(x))] + E_z[log(1 - D(G(z)))]$$

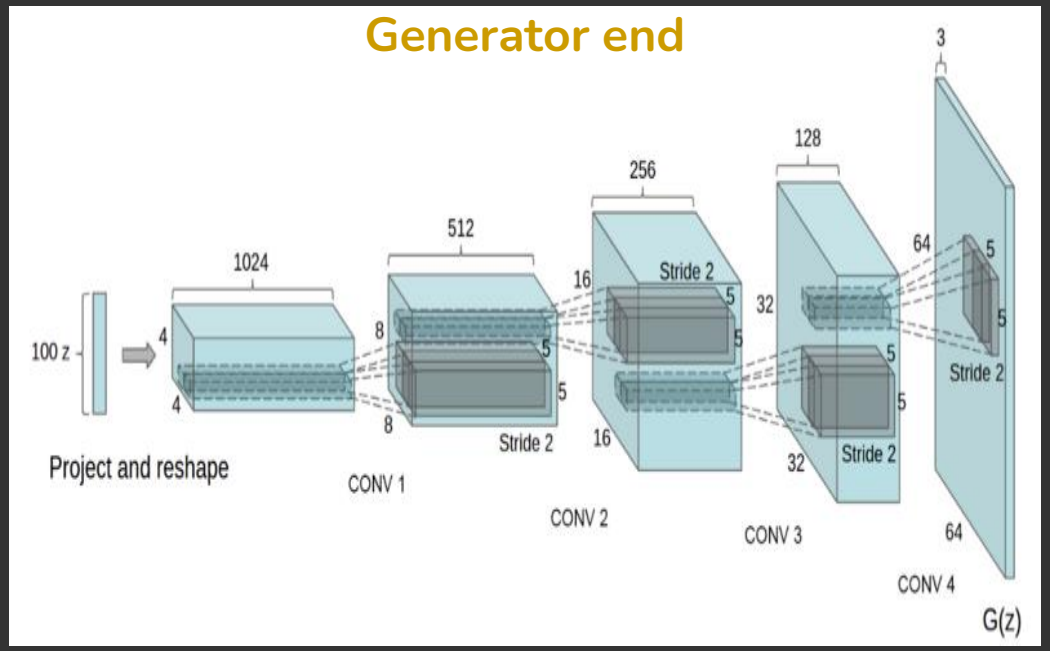
Other loss functions like WGAN-loss, CGAN loss, InfoGAN loss, etc. are subject to the GAN architecture in general

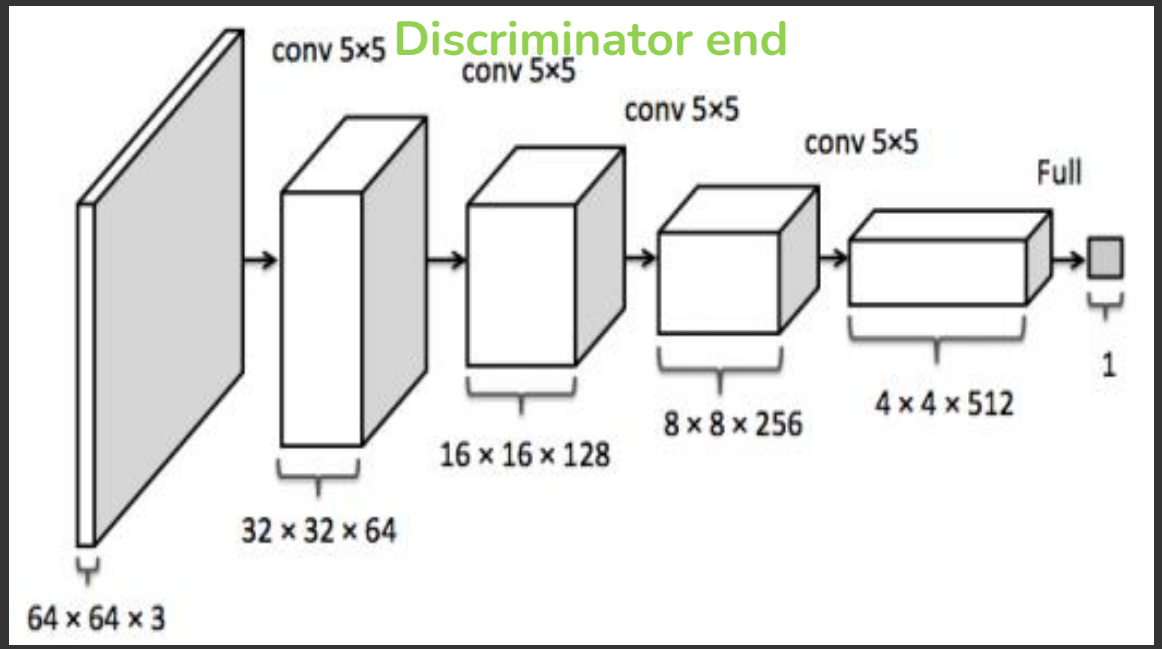
Some problems faced during training

- Vanishing gradients
- Failure in convergence
- Unstable training
- Mode collapse
- Lack of proper evaluation metric to check GAN progress – evolution of loss does not necessarily indicate the reach of equilibrium

Deep Convolutional GAN (DCGAN) [8]

Model architecture



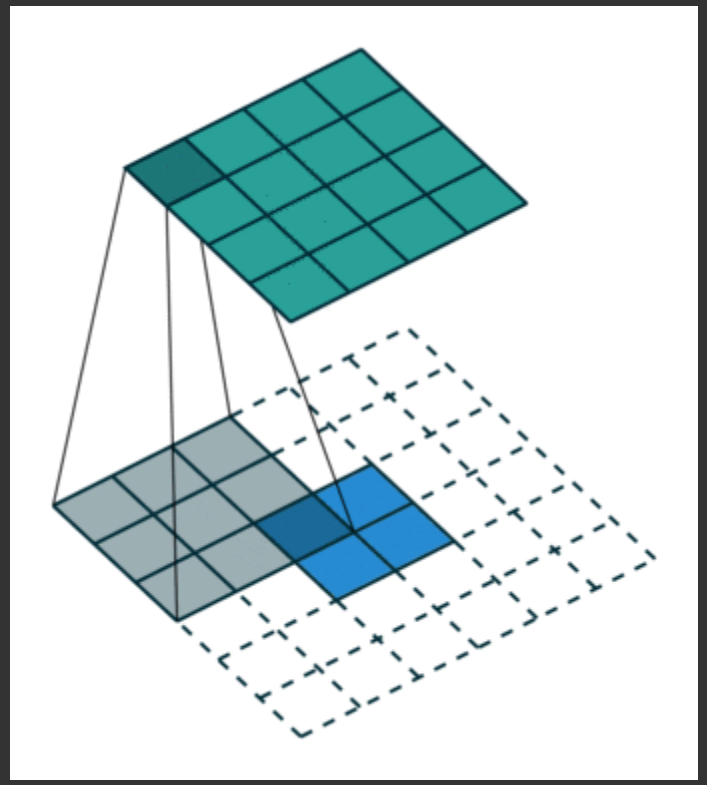


Some important contributions of DCGAN

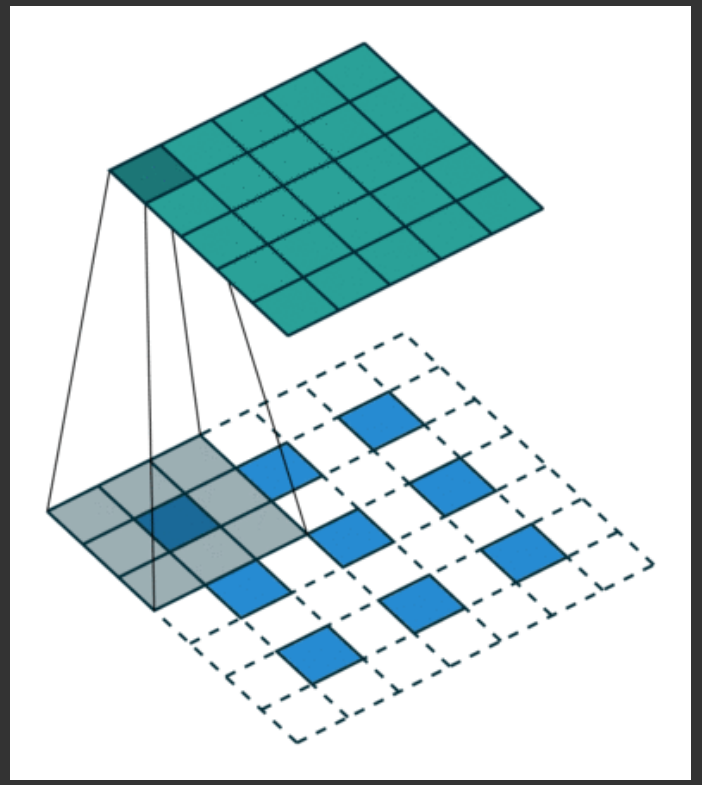
- Replace pooling layers of discriminator (D) with strided conv. layers and those of generator (G) by FRACTIONALLY-STRIDED CONV. layers
- Eliminate fully-connected layers at the end of model
- Use BatchNorm for both G and D
- Use ReLU in G for all layers except last layer, which uses *tanh*
- Use LeakyReLU in D for all layers

Some useful hacks for training a DCGAN (as suggested by its authors [8]) can be found at : Ganhacks

Quick note: Fractionally-strided convolution / Transpose convolution



Input = (2,2)
Stride = (1,1)
Padding = None
Output = (4,4)



Input = (3,3)
Stride = (2,2)
Padding = Valid
Output = (5,5)

- See detailed discussion at https://distill.pub/2016/deconv-checkerboard/
- Find more CONV visualizations at Conv_arithmetic

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Towards implementing DCGAN

- Deep learning framework used : PyTorch
- Dataset : Celeb-A
- Link to code notebook : DCGAN-tutorial
- Outline:
  - ✓ Basic PyTorch pre-requisites
  - ✓ Setup parameters
  - ✓ Data
  - ✓ Weight initializers
  - ✓ Generator and Discriminator architectures
  - ✓ Loss function and optimizer
  - ✓ Training Generator and Discriminator
  - ✓ Results
  - ✓ What can you explore?

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References

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[2] Zhang, Han, et al. "Stackgan: Text to photo-realistic image synthesis with stacked generative adversarial networks." *Proceedings of the IEEE international conference on computer vision*. 2017.

[3] Wang, Yizhi, Yue Gao, and Zhouhui Lian. "Attribute2Font: creating fonts you want from attributes." *ACM Transactions on Graphics (TOG)* 39.4 (2020): 69-1.

[4] Zhang, He, Vishwanath Sindagi, and Vishal M. Patel. "Image de-raining using a conditional generative adversarial network." *IEEE transactions on circuits and systems for video technology* 30.11 (2019): 3943-3956.

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[7] Goodfellow, Ian, et al. "Generative adversarial nets." *Advances in neural information processing systems* 27 (2014).

[8] Radford, Alec, Luke Metz, and Soumith Chintala. "Unsupervised representation learning with deep convolutional generative adversarial networks." *arXiv preprint arXiv:1511.06434* (2015).