MedGAN ID-CGAN CoGAN b-GAN LS-GAN LAPGAN InfoGAN CatGAN LSGAN McGAN MGAN FF-GAN C-VAE-GAN CCGAN MAGAN 3D-GAN DualGAN GAWWN **Bayesian GAN** EBGAN ALI MARTA-GAN f-GAN A++ ArtGAN

LR-GAN CGAN IcGAN DiscoGANMPM-GAN AdaGAN AMGAN iGAN IAN Introduction to GANs SAGAN Ian Goodfellow, Staff Research Scientist, Google Brain MIX+GAN CVPR Tutorial on GANs **BS-GAN** Salt Lake City, 2018-06-22 GoGAN DR-GAN AC-GAN DCGAN BiGAN CycleGAN GP-GAN AnoGAN DTN MAD-GAN AL-CGAN MalGAN BEGAN



Generative Modeling: Density Estimation



Training Data

Density Function



Generative Modeling: Sample Generation



Training Data (CelebA)



Sample Generator (Karras et al, 2017)



(Goodfellow et al., 2014)

Self-Play

1959: Arthur Samuel's checkers agent

(OpenAI, 2017)

(Bansal et al, 2017)

3.5 Years of Progress on Faces

2014

2015

2016

2017

(Brundage et al, 2018)

<2 Years of Progress on ImageNet

Odena et al 2016

Miyato et al 2017

Zhang et al 2018

Self-Attention GAN State of the art FID on ImageNet: 1000 categories, 128x128 pixels

Goldfish

Indigo Bunting

Redshank

Stone Wall

Broccoli

Tiger Cat

Saint Bernard

From GAN to SAGAN

- Depth and Convolution
- Class-conditional generation
- Spectral Normalization
- Hinge loss
- Two-timescale update rule
- Self-attention

No Convolution Needed to Solve Simple Tasks

Original GAN, 2014

Depth and Convolution for Harder Tasks

Original GAN (CIFAR-10)

No convolution

DCGAN (ImageNet)

One convolutional layer

Many convolutional layers (Radford et al, 2015)

From GAN to SAGAN

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Class-Conditional (FANs

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(Mirza and Osindero, 2014)

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AC-GAN: Specialist Generators

monarch butterfly

goldfinch

daisy

redshank

grey whale

(Odena et al, 2016)

SN-GAN: Shared Generator

Gray whale

Welsh springer spaniel

(Miyato et al, 2017)

Persian cat

From GAN to SAGAN

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Spectral Normalization $\sigma(A) := \max_{\mathbf{h}: \mathbf{h} \neq \mathbf{0}} \frac{\|A\mathbf{h}\|_2}{\|\mathbf{h}\|_2} = \max_{\|\mathbf{h}\|_2 < 1} \|A\mathbf{h}\|_2$

- L+1 $\|f\|_{\mathrm{Lip}} \leq \int \sigma(W^l)$ l=1
- $W_{\rm SN}(W) := W/\sigma(W)$
 - (Miyato et al, 2017)

From GAN to SAGAN

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Hinge Loss

$V_D(\hat{G}, D) = \mathop{\mathrm{E}}_{\boldsymbol{x} \sim q_{\text{data}}(\boldsymbol{x})} \left[\min\left(0, -1 + D(\boldsymbol{x})\right) \right] + \mathop{\mathrm{E}}_{\boldsymbol{z} \sim p(\boldsymbol{z})} \left[\min\left(0, -1 - D\left(\hat{G}(\boldsymbol{z})\right)\right) \right]$ $V_G(G, \hat{D}) = - \mathop{\mathrm{E}}_{\boldsymbol{z} \sim p(\boldsymbol{z})} \left[\hat{D} \left(G(\boldsymbol{z}) \right) \right],$

(Miyato et al 2017, Lim and Ye 2017, Tran et al 2017)

From GAN to SAGAN

- Depth and Convolution
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- Two-timescale update rule
- Self-attention

Two-Timescale Update Rule

From GAN to SAGAN

- Depth and Convolution
- Class-conditional generation
- Spectral Normalization
- Hinge loss
- Two-timescale update rule
- Self-attention

Self-Attention

Use layers from Wang et al 2018

Applying GANs

- Semi-supervised Learning
- Model-based optimization
- Extreme personalization
- Program synthesis

Supervised Discriminator for Semi-Supervised Learning

(Odena 2016, Salimans et al 2016)

Semi-Supervised Classification

MNIST: 100 training labels -> 80 test mistakes SVHN: 1,000 training labels -> 4.3% test error CIFAR-10: 4,000 labels -> 14.4% test error (Dai et al 2017)

Designing DNA to optimize protein binding

Personalized GANufacturing

(Hwang et al 2018)

SPIRAL Synthesizing Programs for Images Using Reinforced Adversarial Learning

Input Program end = [(9, 12), (3, 16), (17, 26), (30, 26), (30, 26), (30, 26), (20, 22), (16, 14), (30, 21), ...], <mark>ctl</mark> = [(8, 11), (8, 24), (3, → 25), (10, 25), (18, 25), (23, 25), (17, 21), (17, 22), (18, 22), ...], pen = [0, 1, 1, 1, 1, 1, 0, Image 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0]

(Ganin et al, 2018)

Interpreters

Simulated Paint

Simulated Arm

Real Arm

Other applications

- Planning
- World Models for RL agents
- Fairness and Privacy
- Missing data
- Topics covered at workshop:

 - Inference in other probabilistic models (Mihaela Rosca)
 - Domain adaptation (Judy Hoffman)
 - Imitation Learning (Stefano Ermon)

• Training data for other agents (Philip Isola, Taesung Park, Jun-Yan Zhu)

Cumulative number of named GAN papers by month

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Track updates at the GAN Zoo

https://github.com/hindupuravinash/the-gan-zoo

Questions

