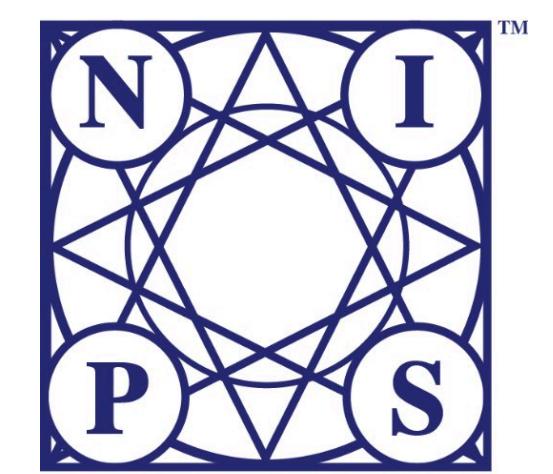


# Triangle Generative Adversarial Networks

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## Contribution

Semi-supervised cross-domain *joint distribution matching*

- Two generators are designed to learn the two-way conditional distributions between the two domains
- Two discriminators implicitly define a ternary discriminative function

## Model

- Original GAN: learn data distribution in *one* domain

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

- Triangle GAN = Cond. GAN + ALI/BiGAN

$$\min_{G_x, G_y} \max_{D_1, D_2} V(G_x, G_y, D_1, D_2) = \mathbb{E}_{(x, y) \sim p(x, y)} [\log D_1(x, y)]$$

$$+ \mathbb{E}_{y \sim p(y), \tilde{x} \sim p_x(x|y)} [\log ((1 - D_1(\tilde{x}, y)) \cdot D_2(\tilde{x}, y))] \\ + \mathbb{E}_{x \sim p(x), \tilde{y} \sim p_y(y|x)} [\log ((1 - D_1(x, \tilde{y})) \cdot (1 - D_2(x, \tilde{y})))]$$

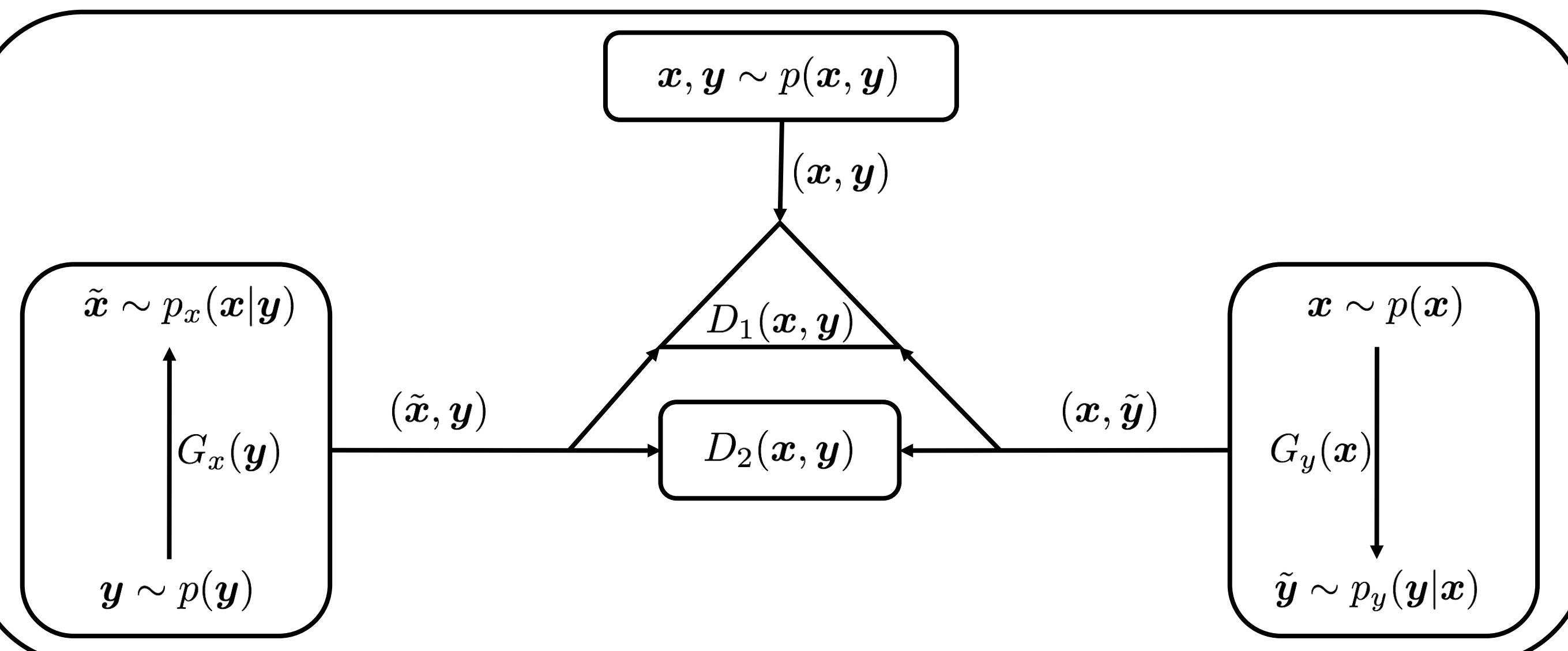
- Blue part accounts for *supervised learning*
- Red part accounts for *unsupervised learning*

## Theorem

The equilibrium of  $V(G_x, G_y, D_1, D_2)$  is achieved if and only if  $p(x, y) = p_x(x, y) = p_y(x, y)$  with  $D_1^*(x, y) = \frac{1}{3}$  and  $D_2^*(x, y) = \frac{1}{2}$ , and the optimum value is  $-3 \log 3$ .

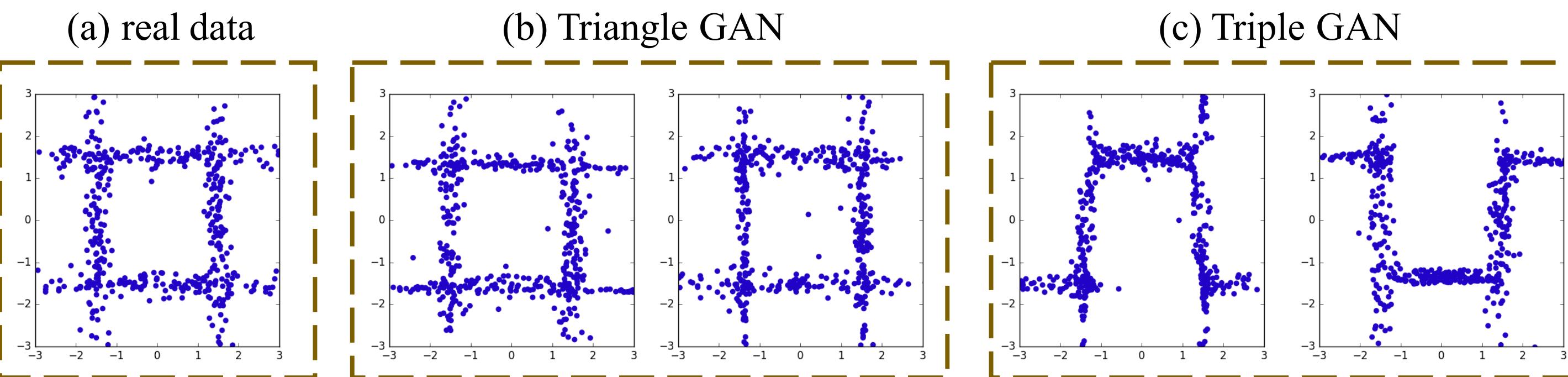
$$C(G_x, G_y) = \max_{D_1, D_2} V(G_x, G_y, D_1, D_2) \\ = -3 \log 3 + 3 \cdot JSD(p(x, y), p_x(x, y), p_y(x, y))$$

## Framework



## Experiment

### Toy data



### Image & label pair

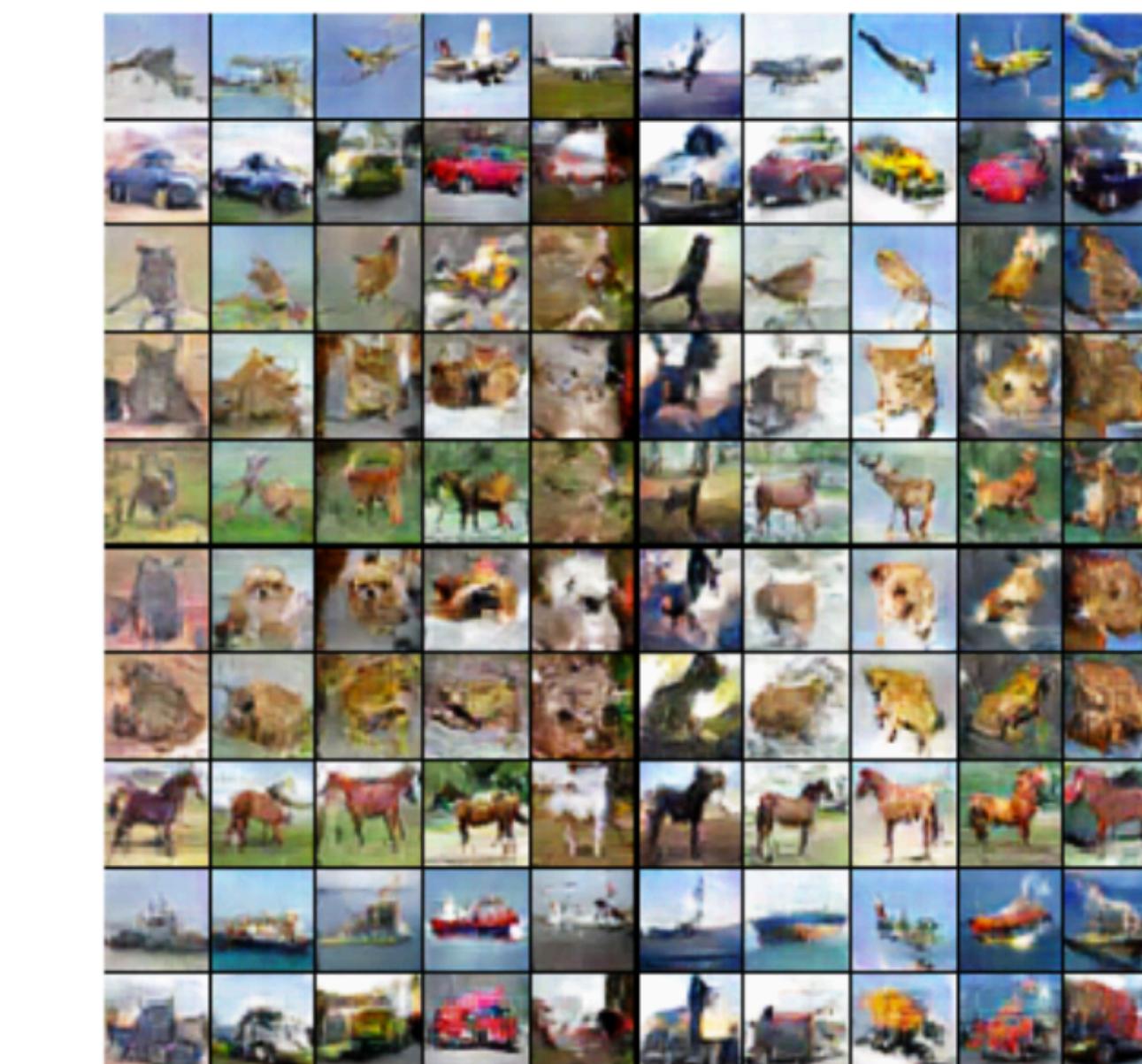


Table 1: Error rates (%) on the partially labeled CIFAR10 dataset.

Algorithm	$n = 4000$
CatGAN [36]	$19.58 \pm 0.58$
Improved GAN [21]	$18.63 \pm 2.32$
ALI [10]	$17.99 \pm 1.62$
Triple GAN [12]	$16.99 \pm 0.36$
$\Delta$ -GAN (ours)	<b><math>16.80 \pm 0.42</math></b>

- Image & image pair: 15% vs. 93% Accuracy

	DiscoGAN	$\Delta$ -GAN
Input:	4 5 0 7	7 5 9 5
Output:	m o b a	~ h m ~ n
Input:	v s o -	o - o ~
Output:	g q b o	8 1 0 g

- Image & attribute pair

Input images	Big Nose, Black Hair, Bushy Eyebrows, Male, Young, Sideburns	Attractive, Smiling, High Cheekbones, Male, High Checkbones, Mouth Slightly Open, Wearing Lipstick	Attractive, Black Hair, Chubby, Goatee, Male, Oval Face, Sideburns, Smiling, Straight Hair	Big Nose, Blond Hair, No Beard, Pointy Nose, Straight Hair, Arched Eyebrows	Attractive, Blond Hair, No Beard, Wavy Hair, Young	High Cheekbones, Heavy Makeup, No Beard, Oval Face, Smiling	Attractive, Brown Hair, Heavy Makeup, No Beard, Wavy Hair, Young	Attractive, Eyeglasses, No Beard, Straight Hair, Wearing Lipstick, Young

1st row+pale skin/mouth slightly open/eyeglasses/wearing hat=2nd row



Input	Predicted attributes	Generated images
	baseball, standing, next, player, man, group, person, field, sport, ball, outdoor, game, grass, crowd	
	sink, shower, indoor, tub, restroom, bathroom, small, standing, room, tile, white, stall, tiled, black, bath	