Feature Generating Networks for Zero-Shot Learning

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Xian Y, Lorenz T, Schiele B, et al. Feature generating networks for zero-shot learning[C]//Proceedings of the IEEE conference on computer vision and pattern recognition. 2018: 5542-5551.

Author





Yongqin Xian

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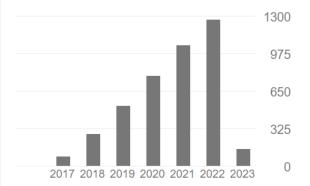
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Zero-shot learning—a comprehensive evaluation of the good, the bad and the ugly SCI基础版工程技术I区 SCI SCIIF 24.31 SWUFE A+ Y Xian, CH Lampert, B Schiele, Z Akata IEEE transactions on pattern analysis and machine intelligence 41 (9), 2251-2265	1208	2018
Feature generating networks for zero-shot learning Y Xian, T Lorenz, B Schiele, Z Akata Proceedings of the IEEE conference on computer vision and pattern	790	2018
Latent embeddings for zero-shot classification Y Xian, Z Akata, G Sharma, Q Nguyen, M Hein, B Schiele Proceedings of the IEEE conference on computer vision and pattern	712	2016
Zero-shot learning-the good, the bad and the ugly Y Xian, B Schiele, Z Akata Proceedings of the IEEE conference on computer vision and pattern	654	2017
f-vaegan-d2: A feature generating framework for any-shot learning Y Xian, S Sharma, B Schiele, Z Akata Proceedings of the IEEE/CVF conference on computer vision and pattern	362	2019
Attribute prototype network for zero-shot learning EI检索 W Xu, Y Xian, J Wang, B Schiele, Z Akata Advances in Neural Information Processing Systems 33, 21969-21980	112	2020

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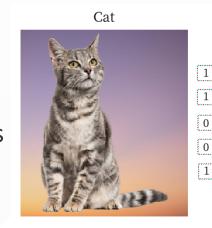
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Zero-Shot Learning



ZSL 目标

ZSL 旨在训练个模型,该模型能够通过<mark>语义信息</mark>的辅助,利用从 seen classes 中学到的知识来对 unseen classes 进行分类。



,.....

Tail 1
Fur 0

Beak 1
Feathers 1

Whiskers 0

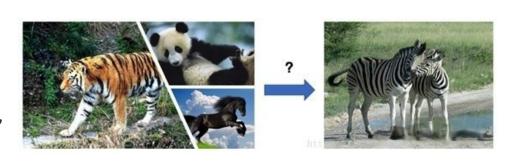


ZSL 所用数据

- ullet seen classes: X^s (图像特征), Y^s (类别标签), A^s (语义信息)
- unseen classes: A^u (语义信息)

举例说明

- 1. 训练集有马、老虎、熊猫的图片
- 2. 语义信息有形状、条纹、颜色等属性
- 3. 给出斑马的定义:马的形状、老虎的条纹、熊猫的颜色
- 4. 输入斑马的图像,分类器能输出斑马的类别

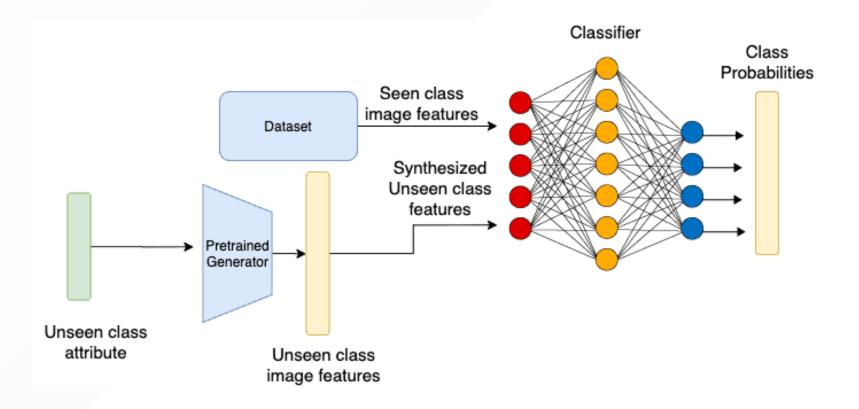


Generative-based Methods



主要思想

- 1. 训练一个生成模型,该模型能够使用语义信息进行条件生成
- 2. 向训练好的模型输入 unseen classes 的语义信息,从而生成 unseen 的样本
- 3. 将训练集中的 seen 样本和生成的 unseen 的样本组合成数据集
- 4. 将数据集输入分类器进行学习,从而使得分类器能对 seen 和 unseen classes 进行分类



论文贡献



- 提出了新的 GAN ——f-xGAN,以语义信息为指导生成特定的特征
- 设置分类 loss, 生成 discriminative 特征
- 做了大量实验,得出了一些重要的结论

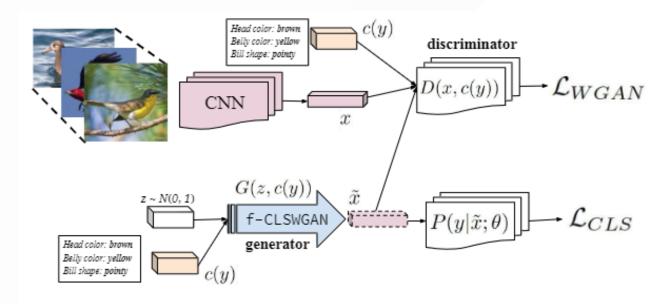


Figure 2: Our f-CLSWGAN: we propose to minimize the classification loss over the generated features and the Wasserstein distance with gradient penalty.

f-GAN



$$egin{aligned} \min_{G} \max_{D} \mathcal{L}_{GAN} = & E[\log D(x, c(y))] + \ & E[\log (1 - D(ilde{x}, c(y)))] \end{aligned}$$

- ullet $D: \mathcal{X} imes \mathcal{C}
 ightarrow [0,1]$
 - 最后一层是 sigmoid
- x: seen classes 的图像特征
- $ilde{x} = G(z,c(y))$: 生成的 seen classes 图像特征
 - z: 高斯噪声
 - \circ c(y): seen classes 的语义信息

f-WGAN



$$egin{aligned} \min_{G} \max_{D} \mathcal{L}_{WGAN} = & E[D(x,c(y))] - E[D(ilde{x},c(y))] - \ & \lambda E[(\|
abla_{\hat{x}}D(\hat{x},c(y))\|-1)^2] \end{aligned}$$

- ullet $D: \mathcal{X} imes \mathcal{C}
 ightarrow \mathbb{R}$
 - 最后一层去除了 sigmoid,输出实数

$$egin{aligned} ullet \hat x &= lpha x + (1-lpha) ilde x \ &\circ lpha \sim U(0,1) \end{aligned}$$

- 前两项代表 Wasserstein distance
- 第三项是 gradient penalty
 - \circ 驱使 D 的梯度沿着真实值和生成值之间的直线具有单位范数
- 不能保证生成 discriminative 的特征

f-CLSWGAN



$$\mathcal{L}_{CLS} = -E_{ ilde{x} \sim p_{ ilde{x}}}[\log P(y| ilde{x}; heta)]$$

- 对于生成的特征,加入一个分类器 loss, 驱使生成的特征易于分类
- θ : 提前用 seen classes 特征训练好的分类器
 - 类别概率计算使用 linear softmax

$$\min_{G} \max_{D} \mathcal{L}_{WGAN} + \beta \mathcal{L}_{CLS}$$

Classification

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Multimodal Embedding

$$f(x) = rg \max_{x} F(x, c(y); W)$$

- F: 基于嵌入的模型
- 相比传统的基于嵌入的方法,这里作者将生成的特征也加入训练

Softmax

$$an egin{aligned} \min_{ heta} -rac{1}{T} \sum_{(x,y) \in \mathcal{T}} \log P(y|x; heta) \ \log P(y|x; heta) = rac{\exp(heta_y^T x)}{\sum_i^N \exp(heta_i^T x)} \end{aligned} \ f(x) = rg \max_y P(y|x; heta)$$

ullet $heta \in \mathbb{R}^{d_x imes N}$



	Zero-Shot Learning					Generalized Zero-Shot Learning										
C	UB	FLO	SUN	AWA		CUB			FLO			SUN			AWA	
G T	T1	T1	T1	T1	u	S	Н	u	S	Н	u	S	Н	u	s	H
ne 52	2.0	45.9	56.5	54.2	23.8	53.0	32.8	9.9	44.2	16.2	16.9	27.4	20.9	13.4	68.7	22.4
-CLSWGAN 60	60.3	60.4	60.9	66.9	52.2	42.4	46.7	45.0	38.6	41.6	38.4	25.4	30.6	35.0	62.8	45.0
ne 5	3.9	53.4	53.7	65.6	23.5	59.2	33.6	13.9	47.6	21.5	14.7	30.5	19.8	11.3	74.6	19.6
-CLSWGAN 58	8.4	67.4	56.5	66.9	48.1	37.4	42.1	52.1	56.2	54.1	36.7	25.0	29.7	37.9	70.1	49.2
ne 49	9.3	40.4	55.3	55.1	15.2	57.3	24.0	6.6	47.6	11.5	14.7	28.8	19.5	7.3	71.7	13.3
-CLSWGAN 60	8.03	60.8	61.3	69.9	53.6	39.2	45.3	47.2	37.7	41.9	42.4	23.1	29.9	33.0	61.5	43.0
ne 5	3.9	51.0	54.5	58.2	12.6	63.8	21.0	11.4	56.8	19.0	11.0	27.9	15.8	6.6	75.6	12.1
-CLSWGAN 54	4.7	54.3	54.0	63.9	36.8	50.9	43.2	25.3	69.2	37.1	27.8	20.4	23.5	31.1	72.8	43.6
ne 54	4.9	48.5	58.1	59.9	23.7	62.8	34.4	13.3	61.6	21.9	21.8	33.1	26.3	16.8	76.1	27.5
-CLSWGAN 61	1.5	71.2	62.1	68.2	40.2	59.3	47.9	54.3	60.3	57.1	41.3	31.1	35.5	47.6	57.2	52.0
ne	_	_	_	_	_	_	_	_	-	_	_	-	_	_	_	_
-CLSWGAN 5	7.3	67.2	60.8	68.2	43.7	57.7	49.7	59.0	73.8	65.6	42.6	36.6	39.4	57.9	61.4	59.6
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51.0 54.5 58.2 12.6 CLSWGAN 54.7 54.3 54.0 63.9 36.8 Ine 54.9 48.5 58.1 59.9 23.7 CLSWGAN 61.5 71.2 62.1 68.2 40.2 Ine - - - - - - - - Ine - - - - - - - -	CUB FLO SUN AWA CUB Ine 52.0 45.9 56.5 54.2 23.8 53.0 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 Ine 53.9 53.4 53.7 65.6 23.5 59.2 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 Ine 49.3 40.4 55.3 55.1 15.2 57.3 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 Ine 53.9 51.0 54.5 58.2 12.6 63.8 CLSWGAN 54.7 54.3 54.0 63.9 36.8 50.9 Ine 54.9 48.5 58.1 59.9 23.7 62.8 CLSWGAN 61.5 71.2 62.1 68.2 40.2 59.3 Ine - - - - - - - - <td>CUB FLO SUN AWA CUB T1 T1 T1 T1 u s H ne 52.0 45.9 56.5 54.2 23.8 53.0 32.8 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 ne 53.9 53.4 53.7 65.6 23.5 59.2 33.6 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 ne 49.3 40.4 55.3 55.1 15.2 57.3 24.0 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 ne 53.9 51.0 54.5 58.2 12.6 63.8 21.0 CLSWGAN 54.7 54.3 54.0 63.9 36.8 50.9 43.2 ne 54.9 48.5 58.1 59.9 23.7 62.8 34.4 <tr< td=""><td>CUB FLO SUN AWA CUB Ine 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65.6 23.5 59.2 33.6 13.9 47.6 21.5 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 Ine 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 11.5 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9 Ine 53.9 51.0 54.5 58.2 12.6 63.8 21.0 11.4 56.8 19.0 CLSWGAN 54.7 5</td><td>CUB FLO SUN AWA CUB FLO T1 T1 T1 T1 u s H u s H u Ine 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 44.2 16.2 16.9 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 Ine 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 Ine 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 11.5 14.7 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9<td>CUB FLO SUN AWA CUB FLO FLO SUN Ine 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 44.2 16.2 16.9 27.4 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 25.4 Ine 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 30.5 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 25.0 Ine 49.3 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59.2 33.6 13.9 47.6 21.5 14.7 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 Ine 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 11.5 14.7 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9<td>CUB FLO SUN AWA CUB FLO FLO SUN Ine 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 44.2 16.2 16.9 27.4 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 25.4 Ine 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 30.5 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 25.0 Ine 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 11.5 14.7 28.8 CLSWGAN 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9 42.4 23.1 Ine 54.</td><td>CUB FLO SUN AWA CUB FLO FLO SUN Inc T1 T1 T1 T1 u s H u s H u s H CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 25.4 30.6 Inc 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 30.5 19.8 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 25.0 29.7 Inc 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 11.5 14.7 28.8 19.5 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9</td><td>CUB FLO SUN AWA CUB FLO FLO SUN AWA T1 T1 T1 T1 u s H u s S H u</td><td>CUB FLO SUN AWA CUB FLO SUN SUN AWA Inc 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 44.2 16.2 16.9 27.4 20.9 13.4 68.7 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 25.4 30.6 35.0 62.8 Inc 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 30.5 19.8 11.3 74.6 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 25.0 29.7 37.9 70.1 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9 42.4 23.1 29.9 33.0</td></td></tr<>	CUB FLO SUN AWA CUB Ine 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 Ine 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 Ine 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 Ine 53.9 51.0 54.5 58.2 12.6 63.8 21.0 11.4 CLSWGAN 54.7 54.3 54.0 63.9 36.8 50.9 43.2 25.3 Ine 54.9 48.5 58.1 59.9 23.7 62.8 34.4	CUB FLO SUN AWA CUB FLO Ine 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 44.2 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 Ine 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 Ine 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 Ine 53.9 51.0 54.5 58.2 12.6 63.8 21.0 11.4 56.8 CLSWGAN 54.7 54.3 54.0 63.9 36.8 50.9 43.2 25.3 6	CUB FLO SUN AWA CUB FLO Ine 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 44.2 16.2 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 Ine 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 Ine 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 11.5 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9 Ine 53.9 51.0 54.5 58.2 12.6 63.8 21.0 11.4 56.8 19.0 CLSWGAN 54.7 5	CUB FLO SUN AWA CUB FLO T1 T1 T1 T1 u s H u s H u Ine 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 44.2 16.2 16.9 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 Ine 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 Ine 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 11.5 14.7 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9 <td>CUB FLO SUN AWA CUB FLO FLO SUN Ine 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 44.2 16.2 16.9 27.4 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 25.4 Ine 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 30.5 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 25.0 Ine 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 11.5 14.7 28.8 CLSWGAN 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9 42.4 23.1 Ine 54.</td> <td>CUB FLO SUN AWA CUB FLO FLO SUN Inc T1 T1 T1 T1 u s H u s H u s H CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 25.4 30.6 Inc 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 30.5 19.8 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 25.0 29.7 Inc 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 11.5 14.7 28.8 19.5 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9</td> <td>CUB FLO SUN AWA CUB FLO FLO SUN AWA T1 T1 T1 T1 u s H u s S H u</td> <td>CUB FLO SUN AWA CUB FLO SUN SUN AWA Inc 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 44.2 16.2 16.9 27.4 20.9 13.4 68.7 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 25.4 30.6 35.0 62.8 Inc 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 30.5 19.8 11.3 74.6 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 25.0 29.7 37.9 70.1 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9 42.4 23.1 29.9 33.0</td>	CUB FLO SUN AWA CUB FLO FLO SUN Ine 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 44.2 16.2 16.9 27.4 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 25.4 Ine 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 30.5 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 25.0 Ine 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 11.5 14.7 28.8 CLSWGAN 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9 42.4 23.1 Ine 54.	CUB FLO SUN AWA CUB FLO FLO SUN Inc T1 T1 T1 T1 u s H u s H u s H CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 25.4 30.6 Inc 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 30.5 19.8 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 25.0 29.7 Inc 49.3 40.4 55.3 55.1 15.2 57.3 24.0 6.6 47.6 11.5 14.7 28.8 19.5 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9	CUB FLO SUN AWA CUB FLO FLO SUN AWA T1 T1 T1 T1 u s H u s S H u	CUB FLO SUN AWA CUB FLO SUN SUN AWA Inc 52.0 45.9 56.5 54.2 23.8 53.0 32.8 9.9 44.2 16.2 16.9 27.4 20.9 13.4 68.7 CLSWGAN 60.3 60.4 60.9 66.9 52.2 42.4 46.7 45.0 38.6 41.6 38.4 25.4 30.6 35.0 62.8 Inc 53.9 53.4 53.7 65.6 23.5 59.2 33.6 13.9 47.6 21.5 14.7 30.5 19.8 11.3 74.6 CLSWGAN 58.4 67.4 56.5 66.9 48.1 37.4 42.1 52.1 56.2 54.1 36.7 25.0 29.7 37.9 70.1 CLSWGAN 60.8 60.8 61.3 69.9 53.6 39.2 45.3 47.2 37.7 41.9 42.4 23.1 29.9 33.0

Table 2: ZSL measuring per-class average Top-1 accuracy (T1) on \mathcal{Y}^u and GZSL measuring $\mathbf{u} = \text{T1}$ on \mathcal{Y}^u , $\mathbf{s} = \text{T1}$ on \mathcal{Y}^s , $\mathbf{H} = \mathbf{harmonic}$ mean (FG=feature generator, none: no access to generated CNN features, hence softmax is not applicable). f-CLSWGAN significantly boosts both the ZSL and GZSL accuracy of all classification models on all four datasets.

- 传统的基于嵌入的方法,加上 FG 后,准确率提高,且平衡了 seen 和 unseen 的分类准确率
- 在 GZSL 下,简单的 Softmax 分类器优于传统的方法



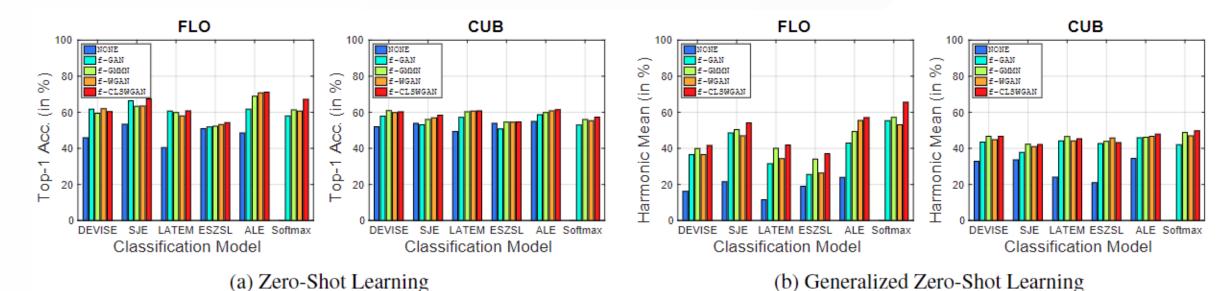


Figure 3: Comparing f-xGAN versions with f-GMMN as well as comparing multimodal embedding methods with softmax.

- 加上 FG 的结果优于 none,即不加 FG
- 在不同的生成模型下,f-CLSWGAN 的效果普遍最好



对于生成的 seen classes 样本进行分类器的训练,并在测试集上测试 seen 准确率

• 稳定性: 随着 Epoch 的增加,分类器对于 seen 的准确率 呈稳定的上升趋势

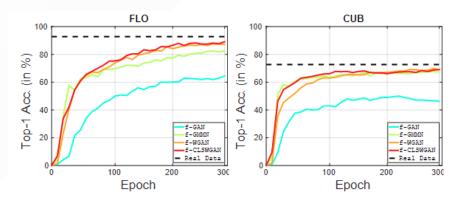


Figure 4: Measuring the seen class accuracy of the classifier trained on generated features of seen classes w.r.t. the training epochs (with softmax).

改变生成的 unseen 样本的数量训练分类器,并在测试集上测试 unseen 准确率

• 泛化性: 随着生成的 unseen 样本的增加,分类器对于 unseen 的准确率呈稳定的上升趋势

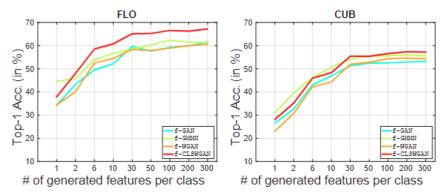


Figure 5: Increasing the number of generated f-xGAN features wrt unseen class accuracy (with softmax) in ZSL.



CNN	FG	\mathbf{u}	\mathbf{s}	H
GoogLeNet	none	20.2	35.7	25.8
GoogleNet	f-CLSWGAN	35.3	38.7	36.9
ResNet-101	none	23.7	62.8	34.4
Resnet-101	f-CLSWGAN	43.7	57.7	49.7

Table 3: GZSL results with GoogLeNet vs ResNet-101 features on CUB (CNN: Deep Feature Encoder Network, FG: Feature Generator, $\mathbf{u} = T1$ on \mathcal{Y}^u , $\mathbf{s} = T1$ on \mathcal{Y}^s , $\mathbf{H} = \mathbf{harmonic mean}$, "none"= no generated features).





С	FG	\mathbf{u}	\mathbf{s}	H
Attribute (att)	none	23.7	62.8	34.4
Aunbuie (act)	f-CLSWGAN	43.7	57.7	49.7
Sentence (stc)	none	38.8	53.8	45.1
Semence (Stc)	f-CLSWGAN	50.3	58.3	54.0

Table 4: GZSL results with conditioning f-xGAN with stc and att on CUB (C: Class embedding, FG: Feature Generator, $\mathbf{u} = T1$ on \mathcal{Y}^u , $\mathbf{s} = T1$ on \mathcal{Y}^s , $\mathbf{H} = \mathbf{harmonic}$ mean, "none"= no generated features).

• 使用 stc 进行生成的效果优于使用 att 进行生成的效果, 说明 stc 能反映出更多的特征



Image 代表从 StackGAN 依据 stc 生成的 256 imes 256 的图像中提取特征

		COL	•	rLO						
Generated Data	\mathbf{u}	\mathbf{s}	H	\mathbf{u}	\mathbf{s}	H				
none	38.8	53.8	45.1	13.3	61.6	21.9				
Image (with [48])	23.8	48.5	31.9	39.4	64.9	49.0				
CNN feature (Ours)	50.3	58.3	54.0	59.0	73.8	65.6				

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Table 5: Summary Table ($\mathbf{u} = T1$ on \mathcal{Y}^u , $\mathbf{s} = T1$ accuracy on \mathcal{Y}^s , $\mathbf{H} =$ harmonic mean, class embedding = stc). "none": ALE with no generated features.

- Image 在 FLO 上有所提高,但在 CUB 上反而降低了
 - 论文中认为生成鸟类比生成花类更难
 - 论文通过目视观察发现,尽管生成了许多鸟类或花类的外观,但缺乏分类所需的判别细节
- 生成图像特征比生成图像的效果要好,论文认为原因在于
 - 生成的图像特征的数量是无限的
 - 图像特征是从ImageNet上训练的模型学习到的低维特征,因此可用规模小的生成模型进行生成
 - 生成的图像特征具有更高的辨识度,因为生成图像的维度要高的多,导致更难区分