# Adversarial Teacher-Student Representation Learning for Domain Generalization

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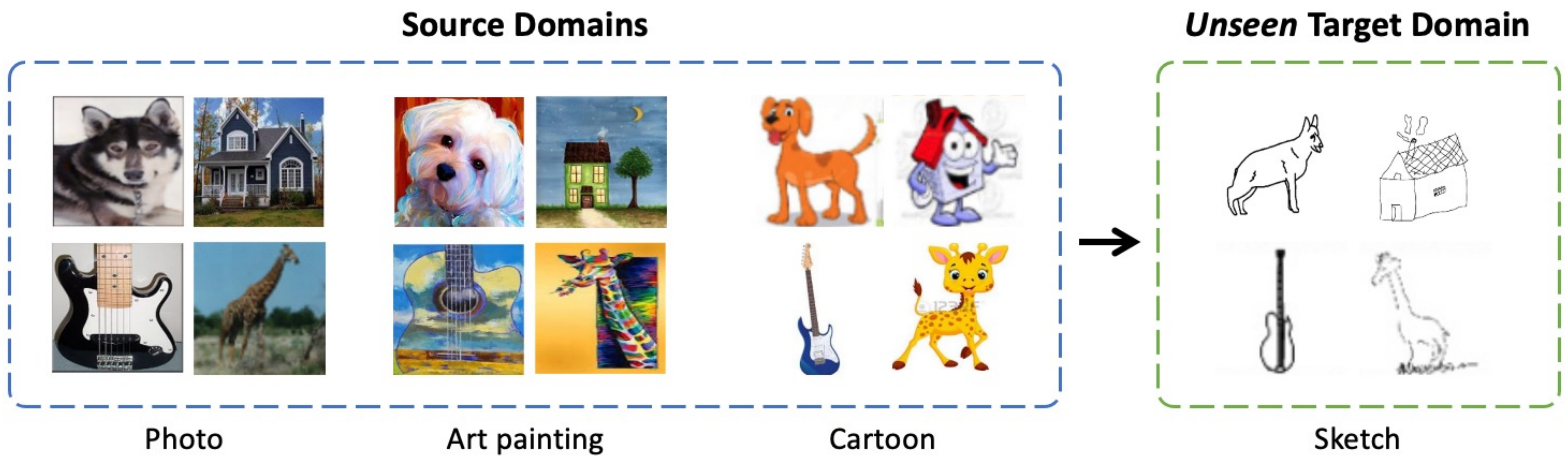
## Goal & Contributions

- **Goal**: Train a model on single or multiple source domain(s) and test on target domains with shared label space

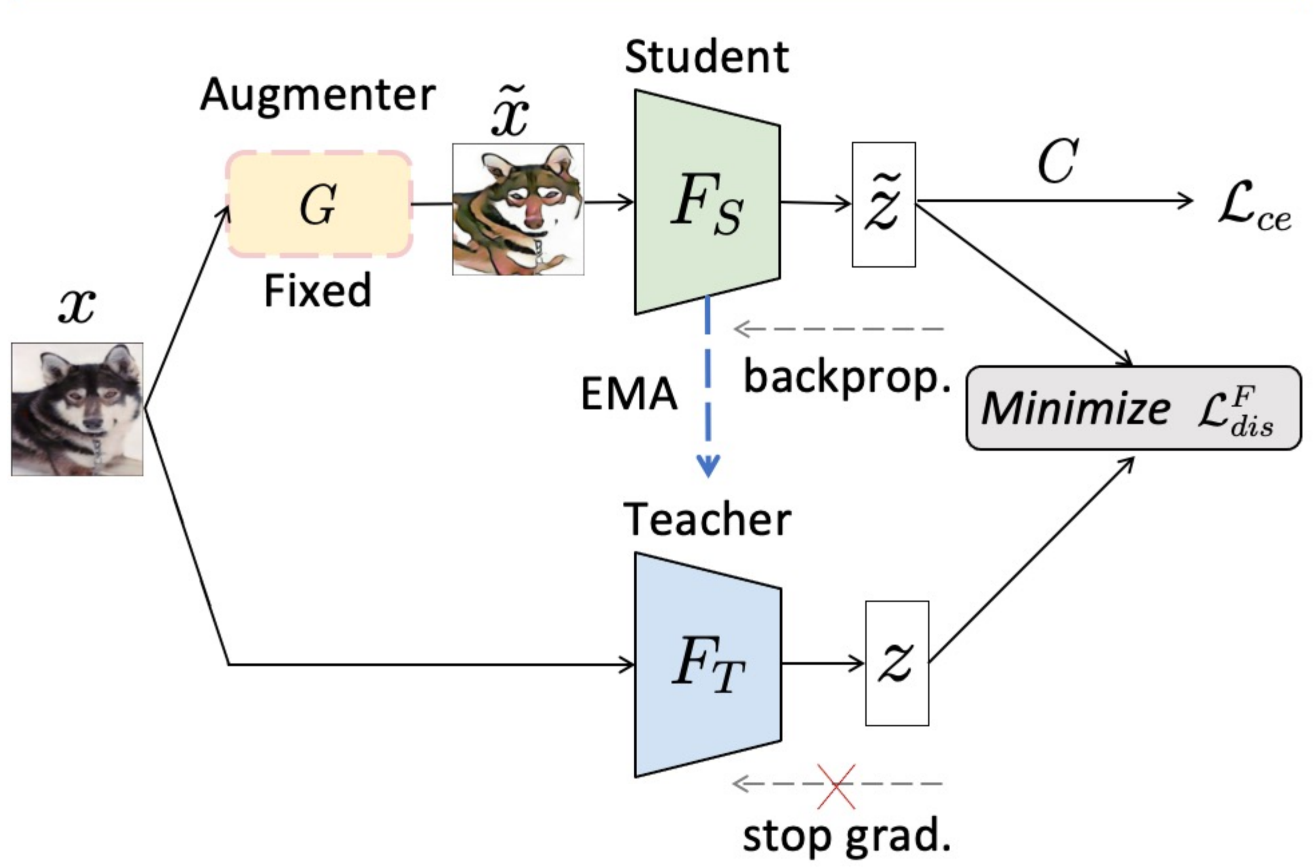



- **Contributions**:

1. Domain Generalized Representation Learning – Student observes augmented novel-domain data and distills the information to update Teacher, allowing derivation of domain generalizable representation.
2. Novel Domain Augmentation – the augmenter aims at producing novel domain data, which maximizes the discrepancy between augmented and existing domains while the semantic information is preserved.

## Adversarial Teacher-Student Representation Learning

### Domain Generalized Representation Learning

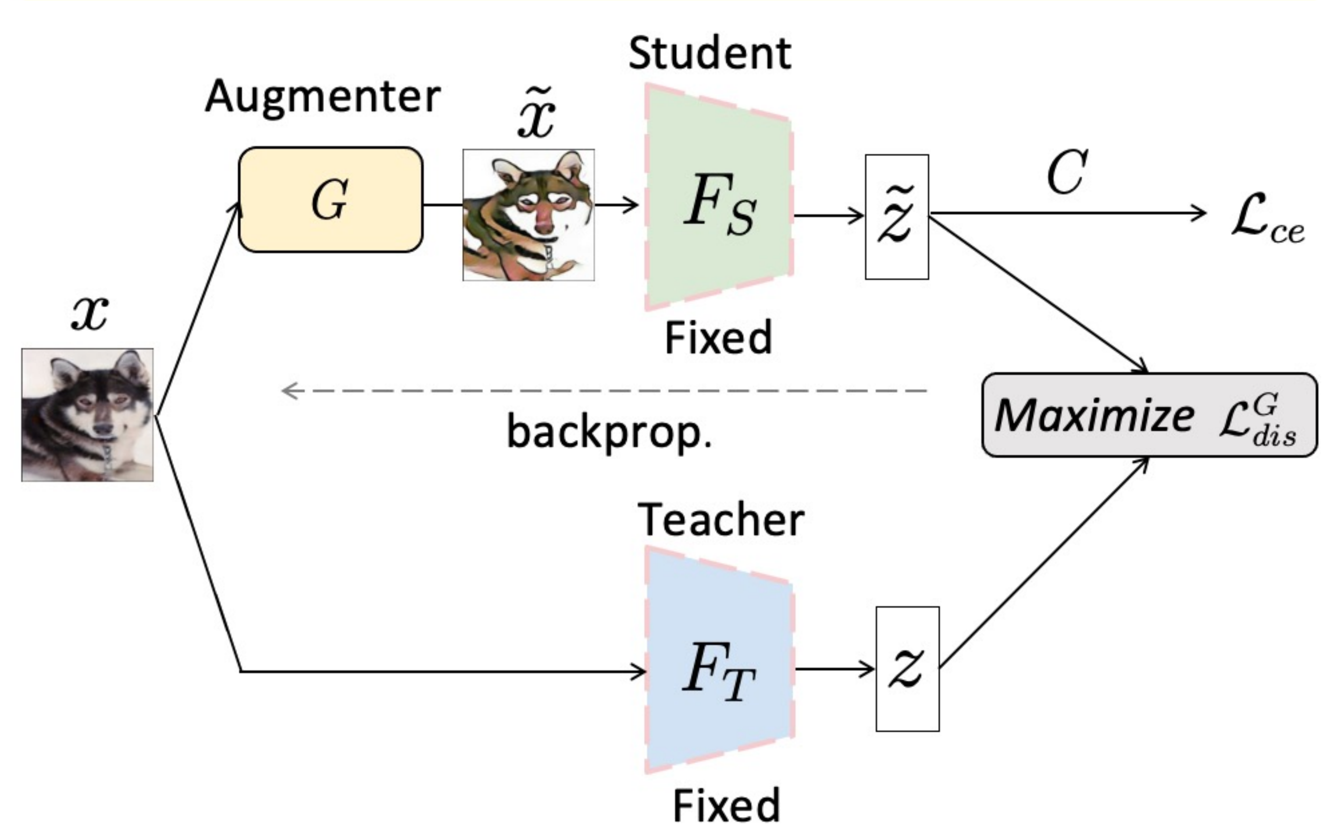



**Minimize** the discrepancy between *Teacher* and *Student* & progressively update *Teacher* via EMA.

$$\min_{F_S} \mathcal{L}^F_{dis}(z,\tilde{z}) = \left\| \frac{z}{\|z\|_2} - \frac{\tilde{z}}{\|\tilde{z}\|_2} \right\|_2^2$$

$$\theta_T \leftarrow \tau\theta_T + (1-\tau)\theta_S, \quad \text{where } \tau \in [0,1)$$

### Novel Domain Augmentation




**Maximize** the discrepancy between augmented and existing domains. The semantic information is preserved via CE loss.

$$\max_{G} \mathcal{L}^G_{dis}(z,\tilde{z}) = \left[\left\| \frac{z}{\|z\|_2} - \frac{\tilde{z}}{\|\tilde{z}\|_2} \right\|_2^2 - m\right]_-$$

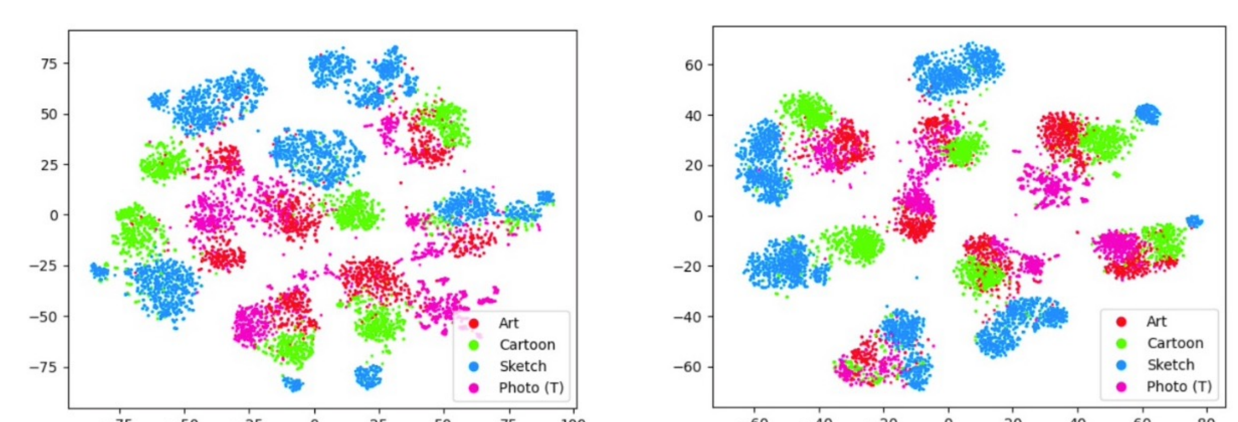
## Experiments

- **Multi-Source DG on PACS in leave-one-domain-out settings**

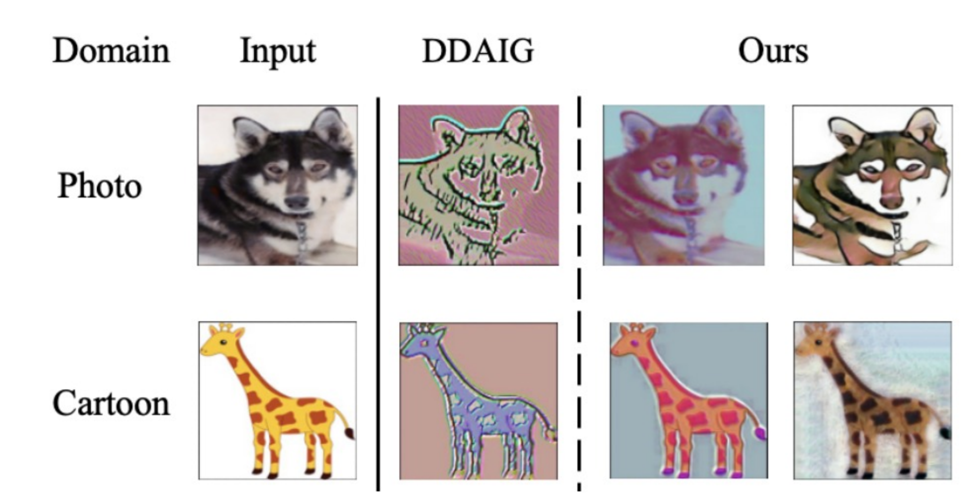
| Target | DeepAll (baseline) | MMD-AAE [1] | MLDG [2] | JiGen [11] | MetaReg [3] | Epi-FCR [4] | MASF [5] | EISNet [12] | DMG [38] | Borlino *et al.* [44] | DSON [45] | RSC [28] | Ours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Photo | 95.6 | 96.0 | 96.1 | 96.0 | 95.5 | 93.9 | 95.0 | 95.9 | 93.4 | 95.0 | 95.9 | 96.0 | **97.3** ± 0.3 |
| Art painting | 75.1 | 75.2 | 81.3 | 79.4 | 83.7 | 82.1 | 80.3 | 81.9 | 76.9 | 82.7 | 84.7 | 83.4 | **85.8** ± 0.6 |
| Cartoon | 74.2 | 72.7 | 77.2 | 75.3 | 77.2 | 77.0 | 77.2 | 76.4 | 80.4 | 78.0 | 77.7 | 80.3 | **80.7** ± 0.5 |
| Sketch | 68.4 | 64.2 | 72.3 | 71.4 | 70.3 | 73.0 | 71.7 | 74.3 | 75.2 | 81.6 | **82.2** | 80.9 | 77.3 ± 0.5 |
| Average | 78.3 | 77.0 | 81.8 | 80.5 | 81.7 | 81.5 | 81.1 | 82.2 | 81.5 | 84.3 | 85.1 | 85.2 | **85.3** |

| Target | ResNet-18 | | | | | | ResNet-50 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | DeepAll (baseline) | CrossGrad [6] | DDAIG [7] | L2A-OT [8] | MixStyle [9] | Ours | DeepAll (baseline) | CrossGrad [6] | DDAIG [7] | MixStyle [9] | Ours |
| Photo | 95.6 | 96.0 | 95.3 | 96.2 | 96.1 | **97.3** ± 0.3 | 94.8 | 97.8 | 95.7 | 98.0 | **98.9** ± 0.3 |
| Art painting | 75.1 | 79.8 | 84.2 | 83.3 | 84.1 | **85.8** ± 0.6 | 81.5 | 87.5 | 85.4 | 87.4 | **90.0** ± 0.3 |
| Cartoon | 74.2 | 76.8 | 78.1 | 78.2 | 78.8 | **80.7** ± 0.5 | 78.6 | 80.7 | 78.5 | 83.3 | **83.5** ± 0.5 |
| Sketch | 68.4 | 70.2 | 74.7 | 73.6 | 75.9 | **77.3** ± 0.5 | 69.7 | 73.9 | **80.0** | 78.5 | **80.0** ± 0.6 |
| Average | 78.3 | 80.7 | 83.1 | 82.8 | 83.7 | **85.3** | 81.2 | 85.7 | 84.9 | 86.8 | **88.1** |

- **t-SNE visualization & visual comparisons on PACS**




(a) DeepAll (b) Our method




- **Single-Source DG on PACS & DomainNet**

| Method | PACS | | | | DomainNet | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Art painting | Cartoon | Sketch | Average | Clipart | Infograph | Painting | Quickdraw | Sketch | Average |
| DeepAll | 60.7 | 23.5 | 29.0 | 37.7 | 34.5 | 15.7 | 40.7 | 3.6 | 25.9 | 24.1 |
| JiGen [11] | 63.6 | 28.5 | 30.2 | 40.8 | 50.0 | 19.0 | 46.3 | 7.2 | 35.5 | 31.6 |
| CrossGrad [6] | 64.2 | 29.4 | 32.1 | 41.9 | 49.4 | 19.3 | 47.3 | 5.8 | 35.6 | 31.5 |
| DDAIG [7] | 64.1 | 32.5 | 29.6 | 42.1 | 41.4 | 16.5 | 40.9 | 3.2 | 26.7 | 25.7 |
| M-ADA [42] | 64.6 | 34.6 | 26.6 | 41.9 | 50.3 | 19.5 | 48.1 | 7.1 | 36.0 | 32.2 |
| **Ours** | **68.2** ± 0.9 | **36.3** ± 0.9 | **33.5** ± 0.3 | **46.0** | **52.2** ± 0.3 | **21.6** ± 0.2 | **50.1** ± 0.2 | **8.1** ± 0.3 | **38.3** ± 0.4 | **34.1** |