



# Rethinking Domain Generalization Baselines

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# Domain Shift

Train Data



Test data





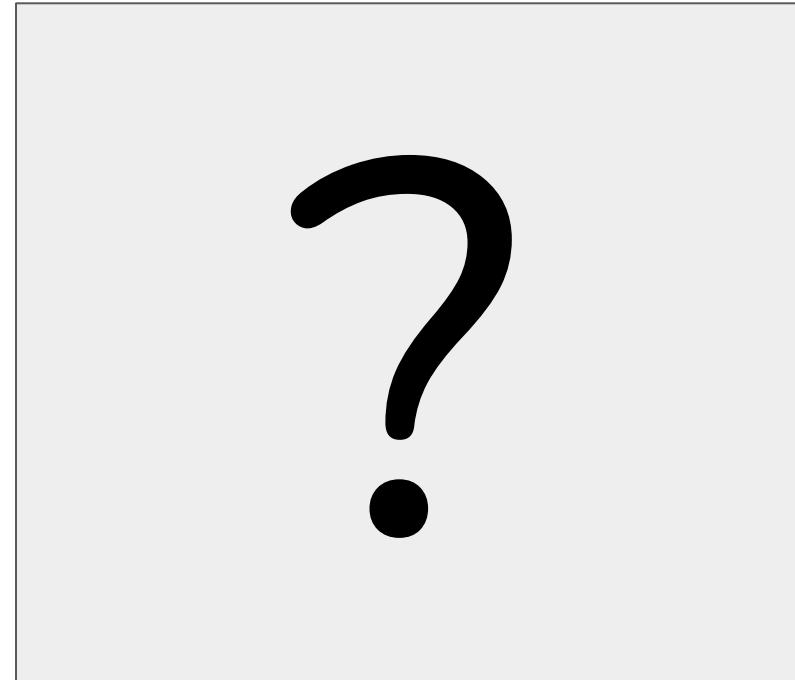
# Domain Shift



Train Data



Test data



# Domain Generalization

Train Data

Source 0



Source 1



Source 2



Test data





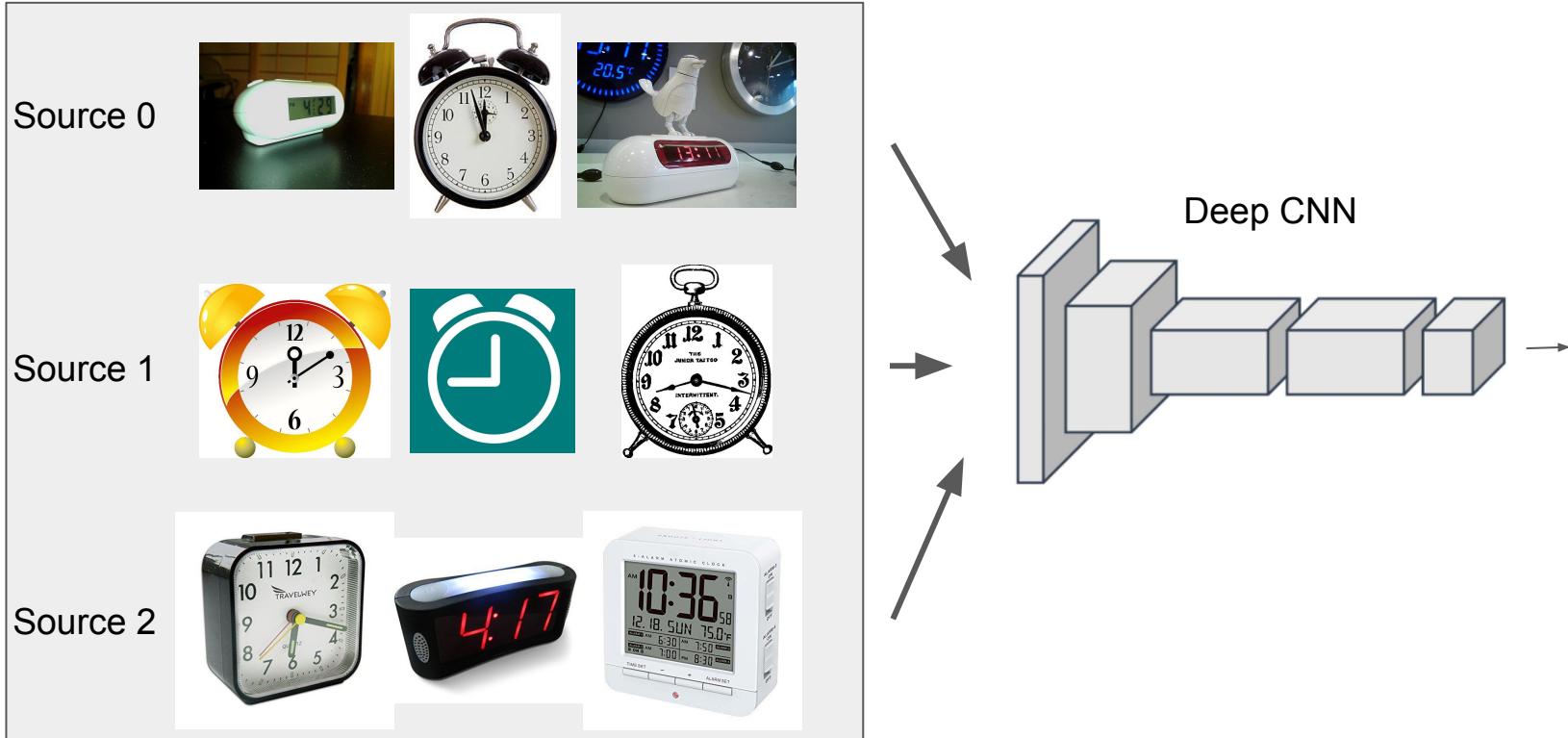
# Domain Generalization Baselines



The logo of the Istituto Italiano di Tecnologia (IIT) consists of the lowercase letters "iit" in a bold, white, sans-serif font, enclosed within a dark grey square.

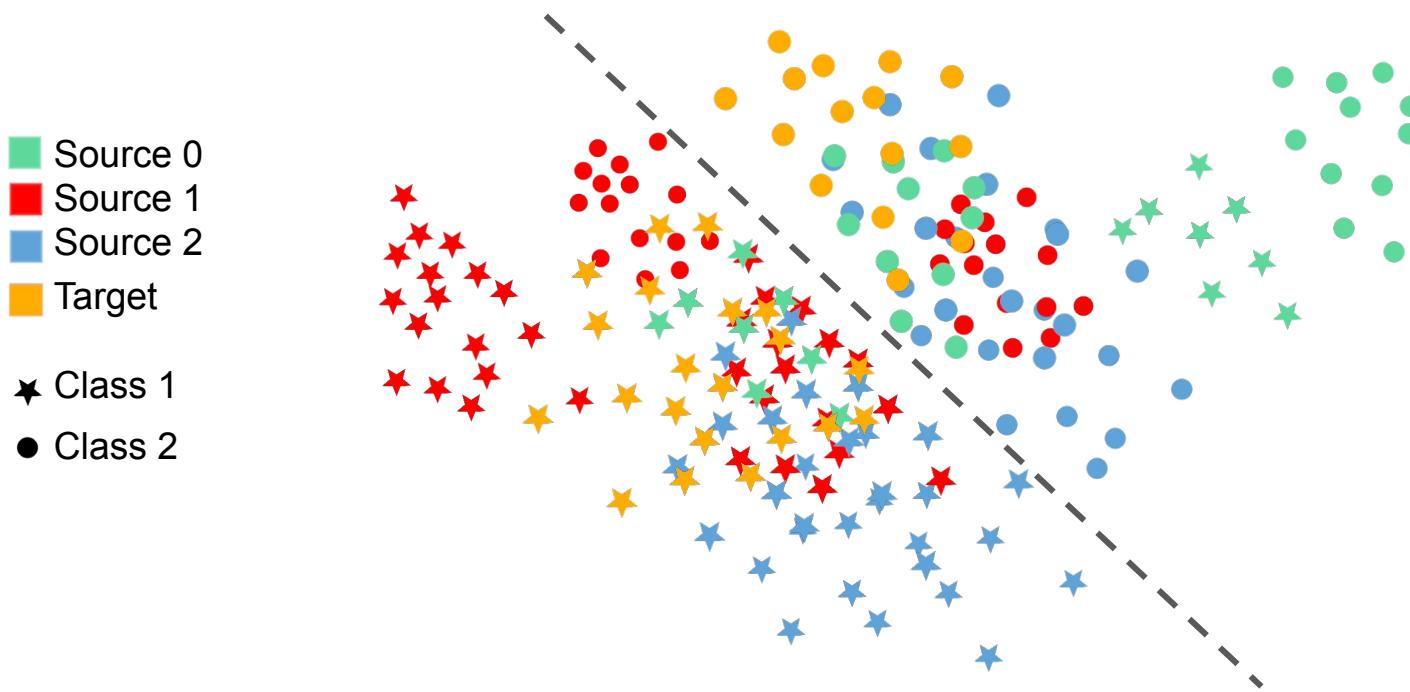


## Train Data



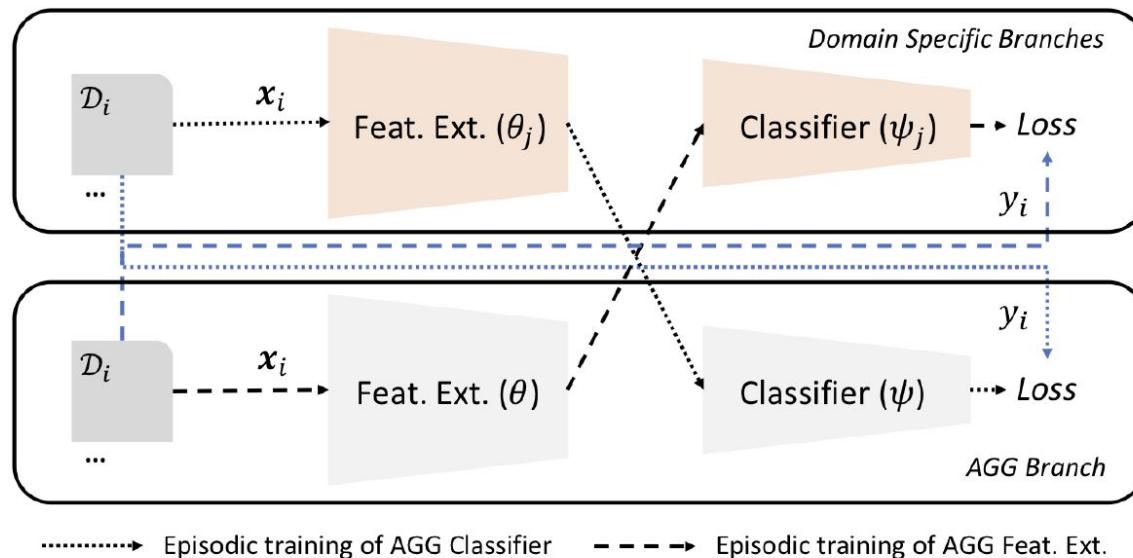
# Previous works

- Capturing the shift at the feature level



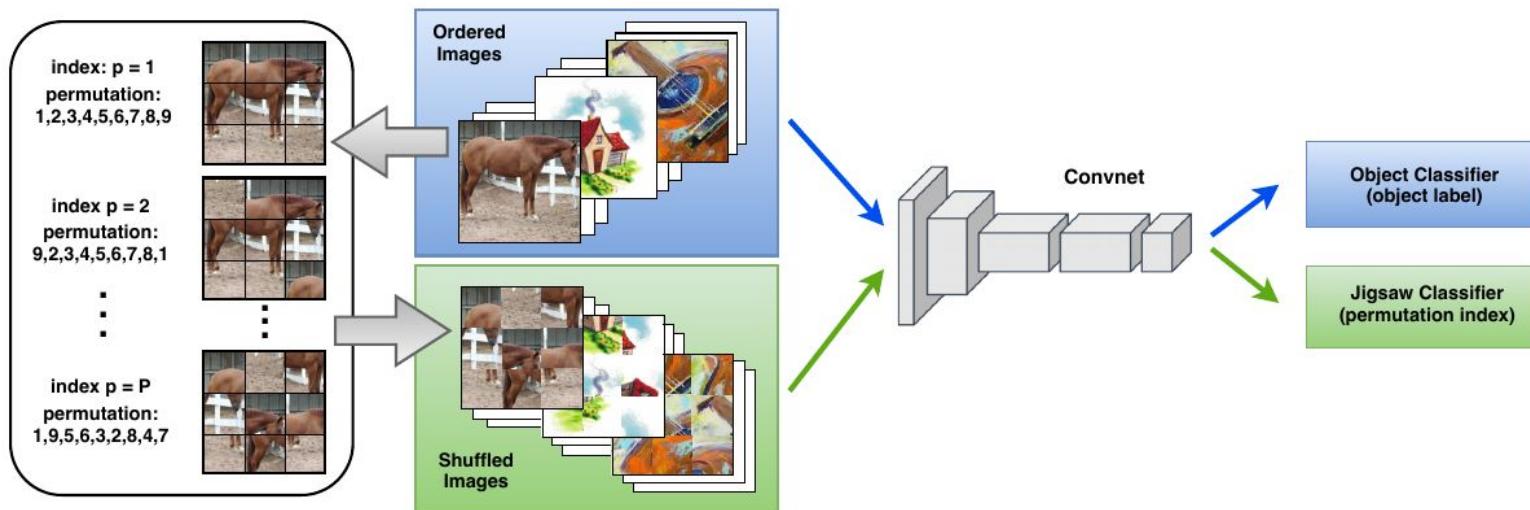
# Previous works

- Capturing the shift at the model level: meta learning



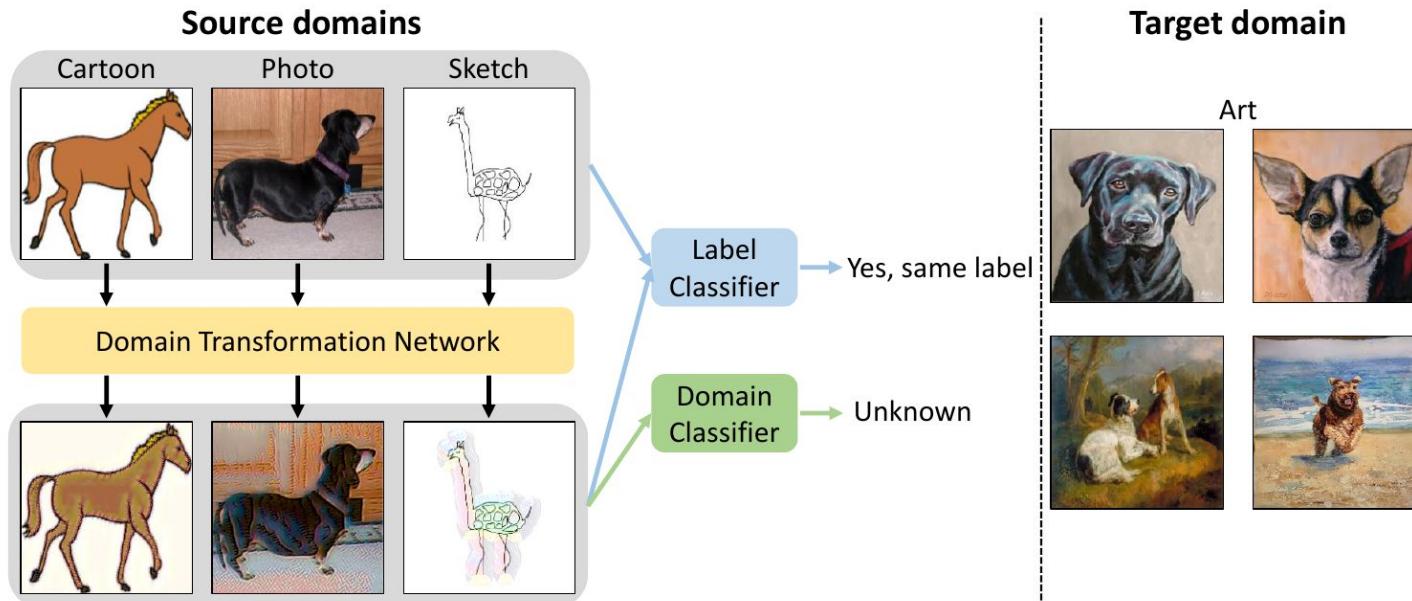
# Previous works

- Capturing the shift at the model level: self supervised learning



# Previous works

- Data augmentation





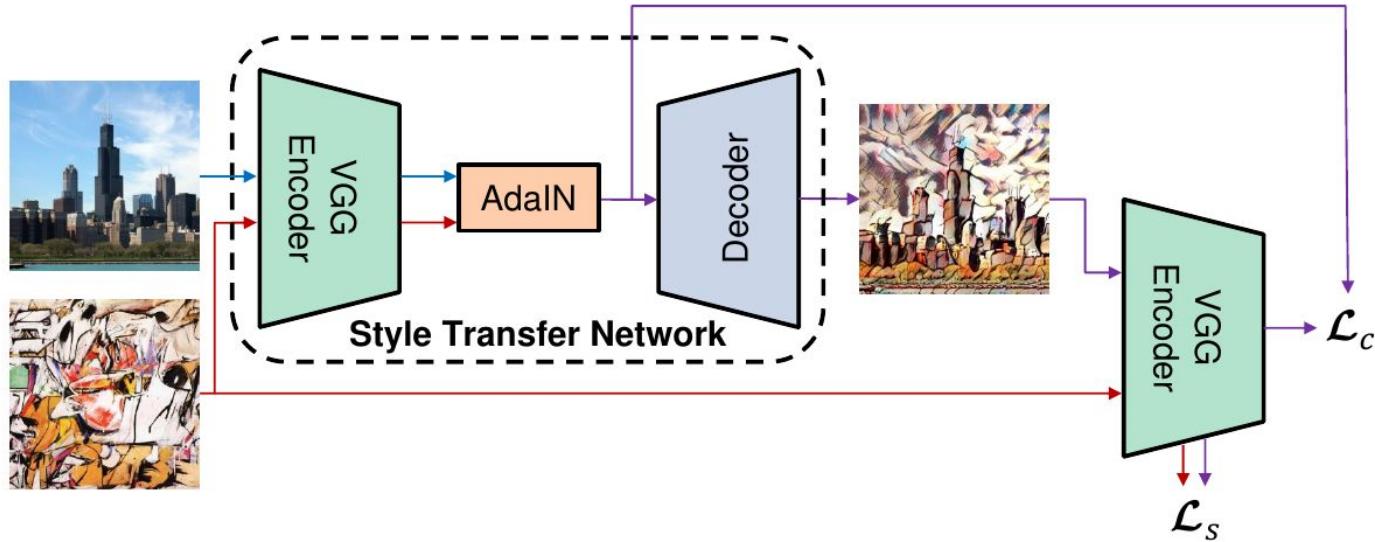
# Current state-of-the-art



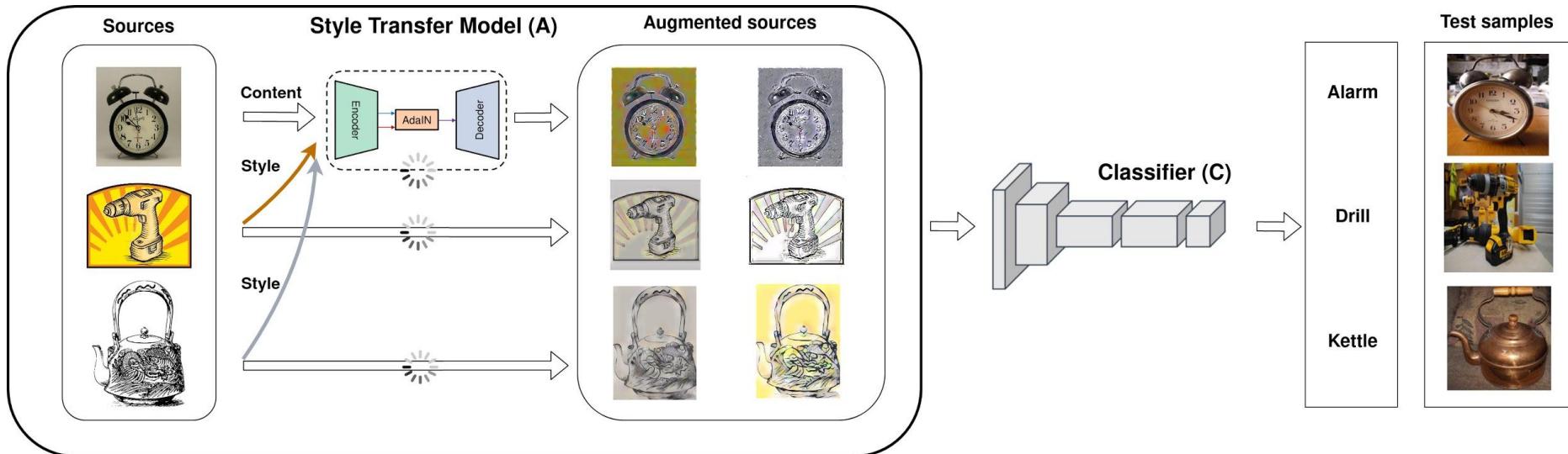
## Our Contributions

- New simple and effective style transfer data augmentation approach
- Tailored strategies to integrate it with feature / model based approaches
- Highlight the need for new strategies able to build over data augmentation ones.

# Style transfer via AdaIN



# Data augmentation via Style transfer





# Comparisons

- **Rotation:** self supervised based approach
  - J. Xu, L. Xiao, and A. M. López, “Self-supervised domain adaptation for computer vision tasks,” IEEE Access, vol. 7, 2019
- **DG-MMLD:** feature alignment based approach
  - T. Matsuura and T. Harada, “Domain generalization using a mixture of multiple latent domains,” in AAAI, 2020
- **EpiFCR:** meta learning based approach
  - D. Li, J. Zhang, Y. Yang, C. Liu, Y.-Z. Song, and T. M. Hospedales, “Episodic training for domain generalization,” in ICCV, 2019
- **DDAIG:** data augmentation based approach
  - K. Zhou, Y. Yang, T. Hospedales, and T. Xiang, “Deep domain-adversarial image generation for domain generalisation,” AAAI, 2020
- **Mixup:** alternative domain mixing strategy
  - H. Zhang, M. Cisse, Y. N. Dauphin, and D. Lopez-Paz, “mixup: Beyond empirical risk minimization,” in ICLR, 2018

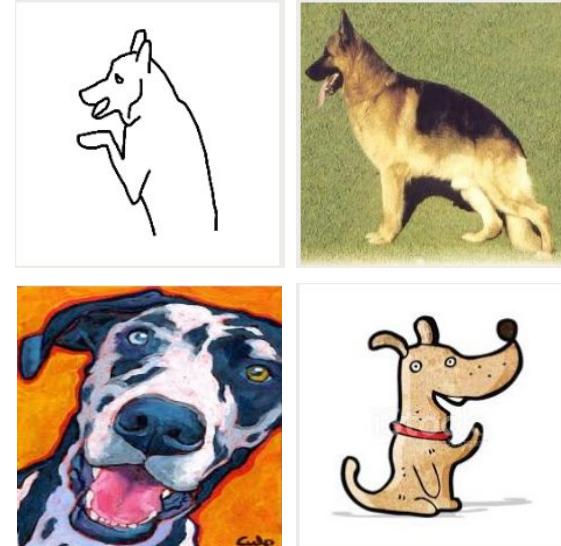
# Results: PACS

|          |               | AlexNet  |         |        |       |         |
|----------|---------------|----------|---------|--------|-------|---------|
|          |               | Painting | Cartoon | Sketch | Photo | Average |
| Original | Baseline      | 66.83    | 70.85   | 59.75  | 89.78 | 71.80   |
|          | Rotation      | 65.66    | 71.89   | 62.15  | 89.88 | 72.39   |
|          | DG-MMLD       | 69.27    | 72.83   | 66.44  | 88.98 | 74.38   |
|          | Epi-FCR       | 64.70    | 72.30   | 65.00  | 86.10 | 72.03   |
|          | DDAIG*        | 62.77    | 67.06   | 58.90  | 86.82 | 68.89   |
| Stylized | Baseline      | 71.96    | 72.47   | 76.47  | 88.34 | 77.31   |
|          | Rotation      | 71.74    | 73.39   | 75.98  | 89.22 | 77.59   |
|          | DG-MMLD       | 70.50    | 70.84   | 75.39  | 88.43 | 76.29   |
|          | Epi-FCR       | 65.19    | 69.54   | 71.97  | 83.43 | 72.53   |
|          | DDAIG         | 69.35    | 71.10   | 70.99  | 87.70 | 74.79   |
| Mixup    | pixel-level   | 66.03    | 68.00   | 51.18  | 88.90 | 68.53   |
|          | feature-level | 67.04    | 69.10   | 55.40  | 88.88 | 70.11   |



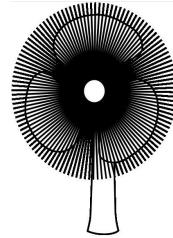
# Results: PACS

|          |               | ResNet18 |         |        |       |         |
|----------|---------------|----------|---------|--------|-------|---------|
|          |               | Painting | Cartoon | Sketch | Photo | Average |
| Original | Baseline      | 77.28    | 73.89   | 67.01  | 95.83 | 78.50   |
|          | Rotation      | 78.16    | 76.64   | 72.20  | 95.57 | 80.64   |
|          | DG-MMLD       | 81.28    | 77.16   | 72.29  | 96.06 | 81.83   |
|          | Epi-FCR       | 82.10    | 77.00   | 73.00  | 93.90 | 81.50   |
|          | DDAIG*        | 79.41    | 74.81   | 69.29  | 95.22 | 79.68   |
| Stylized | Baseline      | 82.73    | 77.97   | 81.61  | 94.95 | 84.32   |
|          | Rotation      | 79.51    | 79.93   | 82.01  | 93.55 | 83.75   |
|          | DG-MMLD       | 80.85    | 77.10   | 77.69  | 95.11 | 82.69   |
|          | Epi-FCR       | 80.68    | 78.87   | 76.57  | 92.50 | 82.15   |
|          | DDAIG         | 81.02    | 78.75   | 79.67  | 95.07 | 83.63   |
| Mixup    | pixel-level   | 78.09    | 71.08   | 66.58  | 93.85 | 77.40   |
|          | feature-level | 81.20    | 76.41   | 69.67  | 96.31 | 80.90   |



# Results: OfficeHome

| ResNet18 |               |       |         |         |            |         |
|----------|---------------|-------|---------|---------|------------|---------|
|          |               | Art   | Clipart | Product | Real World | Average |
| Original | Baseline      | 57.14 | 46.96   | 73.50   | 75.72      | 63.33   |
|          | Rotation      | 55.94 | 47.26   | 72.38   | 74.84      | 62.61   |
|          | DG-MMLD*      | 58.08 | 49.32   | 72.91   | 74.69      | 63.75   |
|          | Epi-FCR*      | 53.34 | 49.66   | 68.56   | 70.14      | 60.43   |
|          | DDAIG*        | 57.79 | 48.32   | 73.28   | 74.99      | 63.59   |
| Stylized | Baseline      | 58.71 | 52.33   | 72.95   | 75.00      | 64.75   |
|          | Rotation      | 57.24 | 52.15   | 72.33   | 73.66      | 63.85   |
|          | DG-MMLD       | 59.24 | 49.30   | 73.56   | 75.85      | 64.49   |
|          | Epi-FCR       | 52.97 | 50.14   | 67.03   | 70.66      | 60.20   |
|          | DDAIG         | 58.21 | 50.26   | 73.81   | 74.99      | 64.32   |
| Mixup    | feature-level | 58.33 | 39.76   | 70.96   | 72.07      | 60.28   |



# Results: VLCS

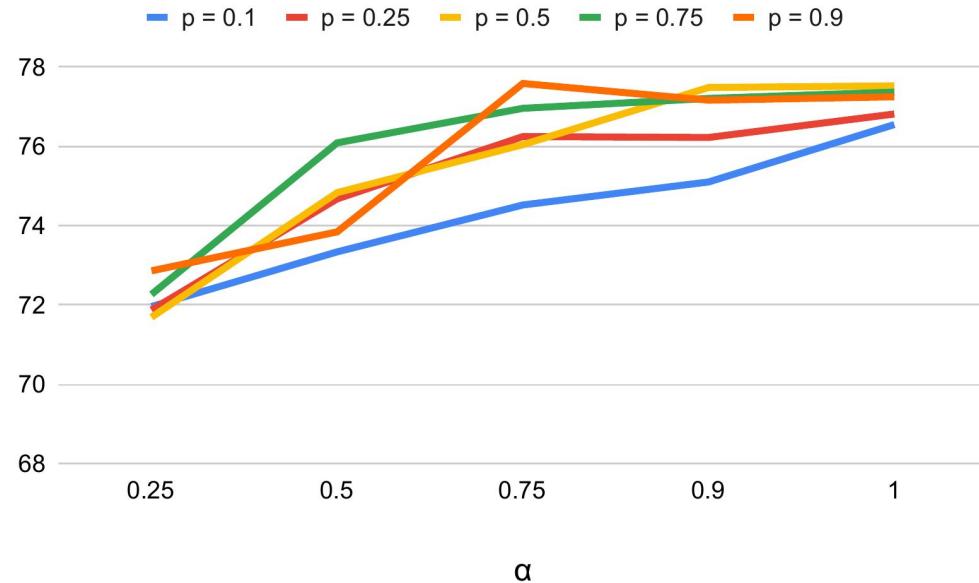
AlexNet

|          |               | CALTECH | LABELME | PASCAL | SUN   | Average |
|----------|---------------|---------|---------|--------|-------|---------|
| Original | Baseline      | 94.89   | 59.14   | 71.31  | 64.64 | 72.49   |
|          | Rotation      | 94.50   | 61.27   | 68.94  | 63.28 | 72.00   |
|          | DG-MMLD*      | 96.94   | 59.10   | 68.48  | 62.06 | 71.64   |
|          | Epi-FCR*      | 91.43   | 61.36   | 63.44  | 60.07 | 69.07   |
|          | DDAIG*        | 95.75   | 60.18   | 65.48  | 60.78 | 70.55   |
| Stylized | Baseline      | 96.86   | 60.77   | 68.18  | 63.42 | 72.31   |
|          | Rotation      | 96.86   | 60.77   | 68.18  | 63.42 | 72.31   |
|          | DG-MMLD       | 97.49   | 61.02   | 64.23  | 62.37 | 71.28   |
|          | Epi-FCR       | 92.69   | 58.18   | 62.59  | 57.87 | 67.83   |
|          | DDAIG         | 97.48   | 60.48   | 65.19  | 62.57 | 71.43   |
| Mixup    | feature-level | 94.73   | 62.15   | 69.82  | 62.98 | 72.42   |

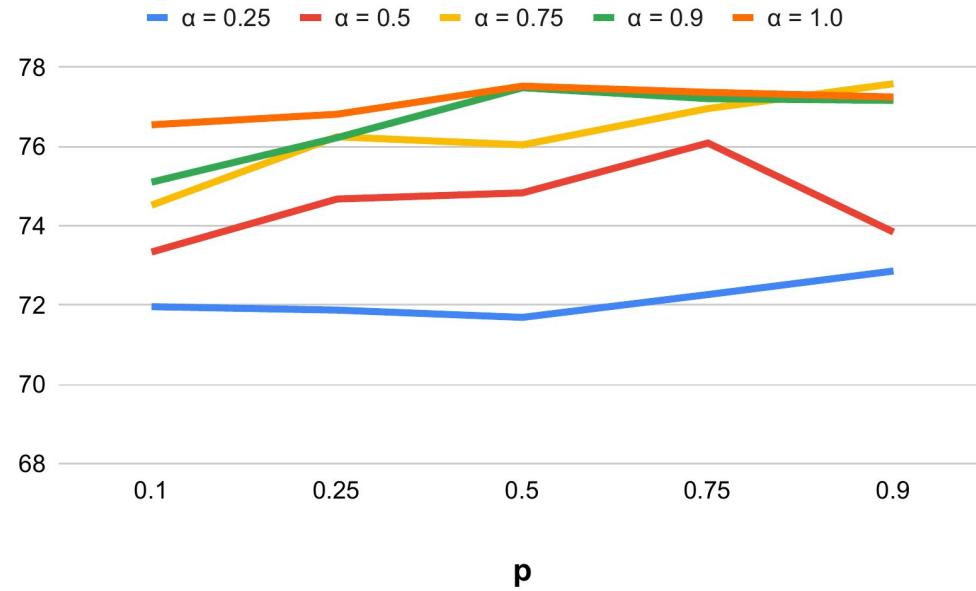


A. Torralba and A. A. Efros, "Unbiased look at dataset bias," in CVPR, 2011.

# Analysis of AdaIN hyperparameters



# Analysis of AdaIN hyperparameters





# Conclusions

- A simple **style-transfer based data augmentation strategy** can be particularly effective in Domain Generalization producing **a new strong baseline**
- Current state of the art approaches do not improve over this new baseline and are not able to take advantage of this data augmentation technique
- We should develop new Domain Generalization strategies able to effectively build on top of the new baseline

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