Domain Adaptation

常琬星

2023/04/26

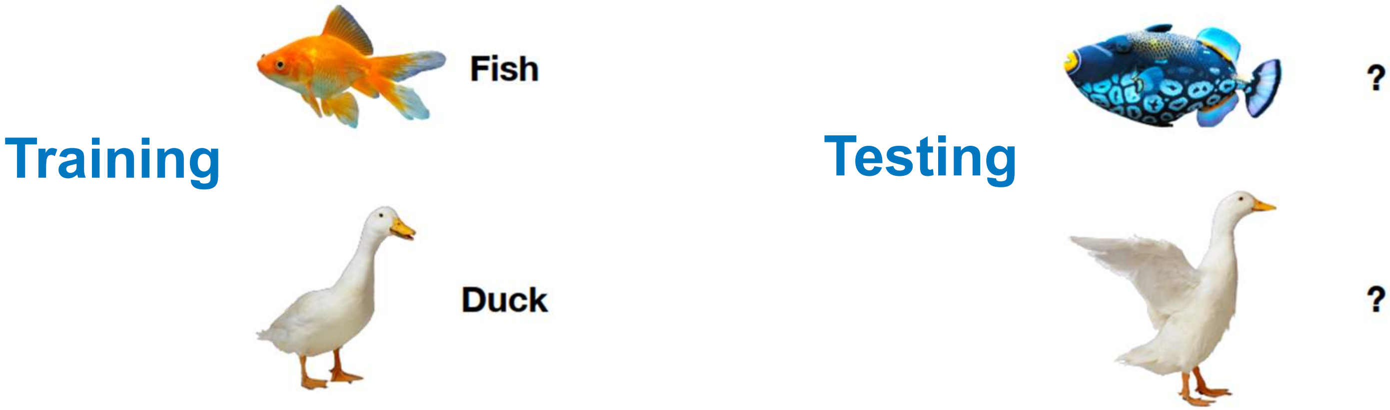
Overview

- Domain Adaptation Foundation
- Domain Adaptation Method
  - Discrepancy-based methods
  - Adversarial-based methods
- Multi-source Domain Adaptation Methods
- Universal Domain Adaptation Methods

A caveat in naive ML

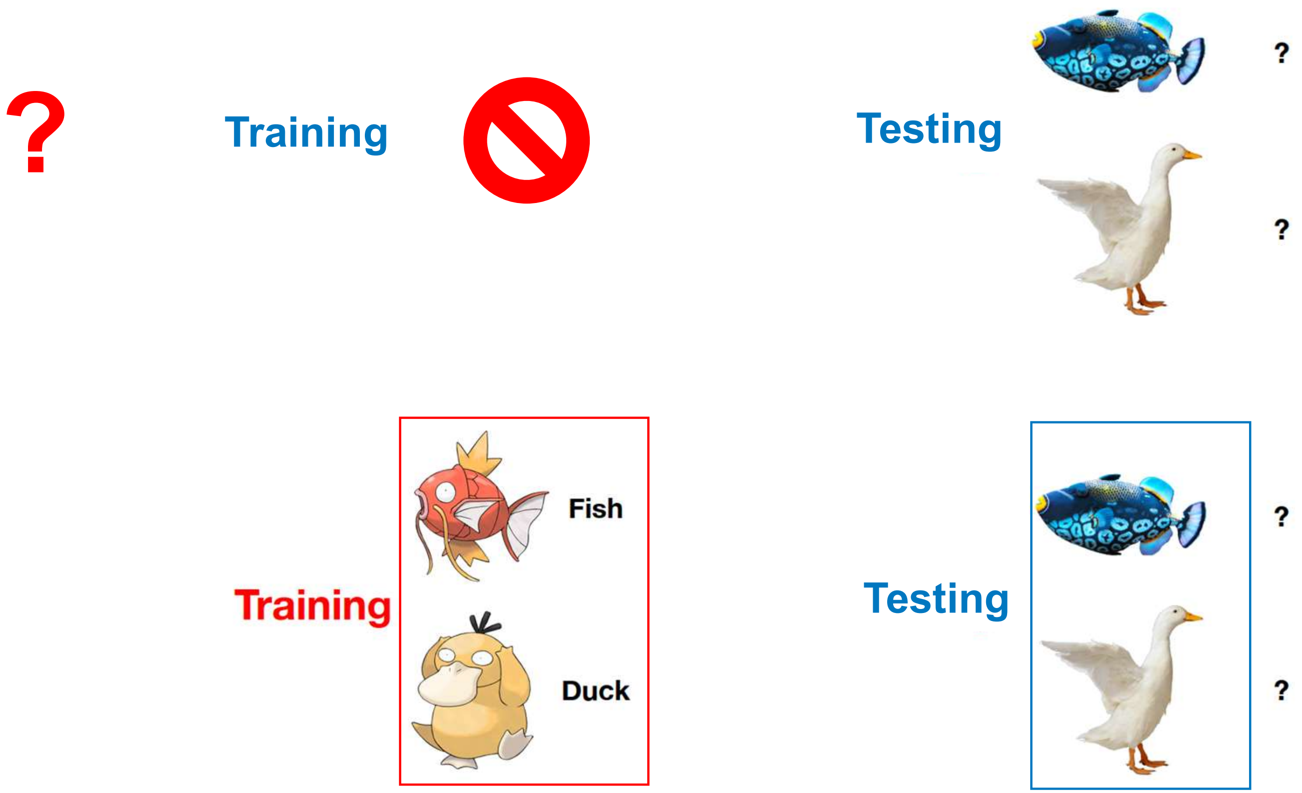
★ **The common assumption in ML is:**

1. **Annotated training data is available.**
2. **Training and testing data is drawn from same feature space with same distribution.**



Slide credit: Chonghao Zhao

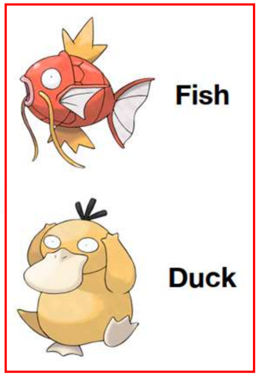
Not enough training data, No labels for training data…



Slide credit: Chonghao Zhao

Why Domain Adaptation?

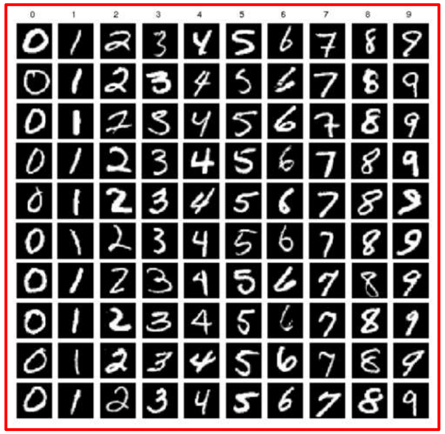
Training



Testing

?

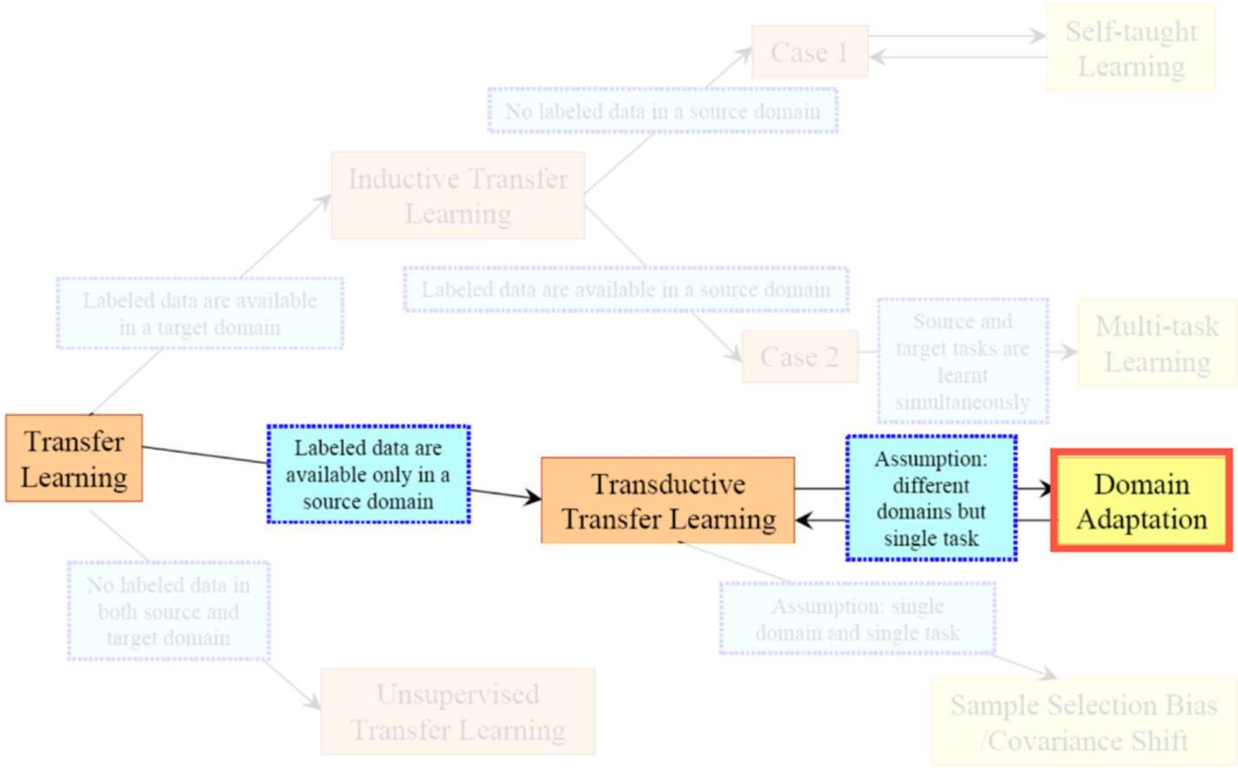
?



ACC 5%

Slide credit: Chonghao Zhao

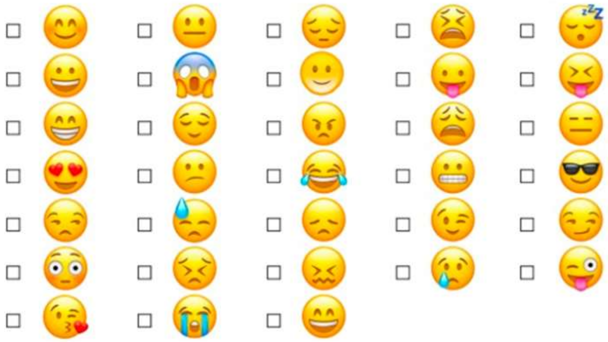
Transfer learning vs Domain Adaptation



Slide credit: Chonghao Zhao

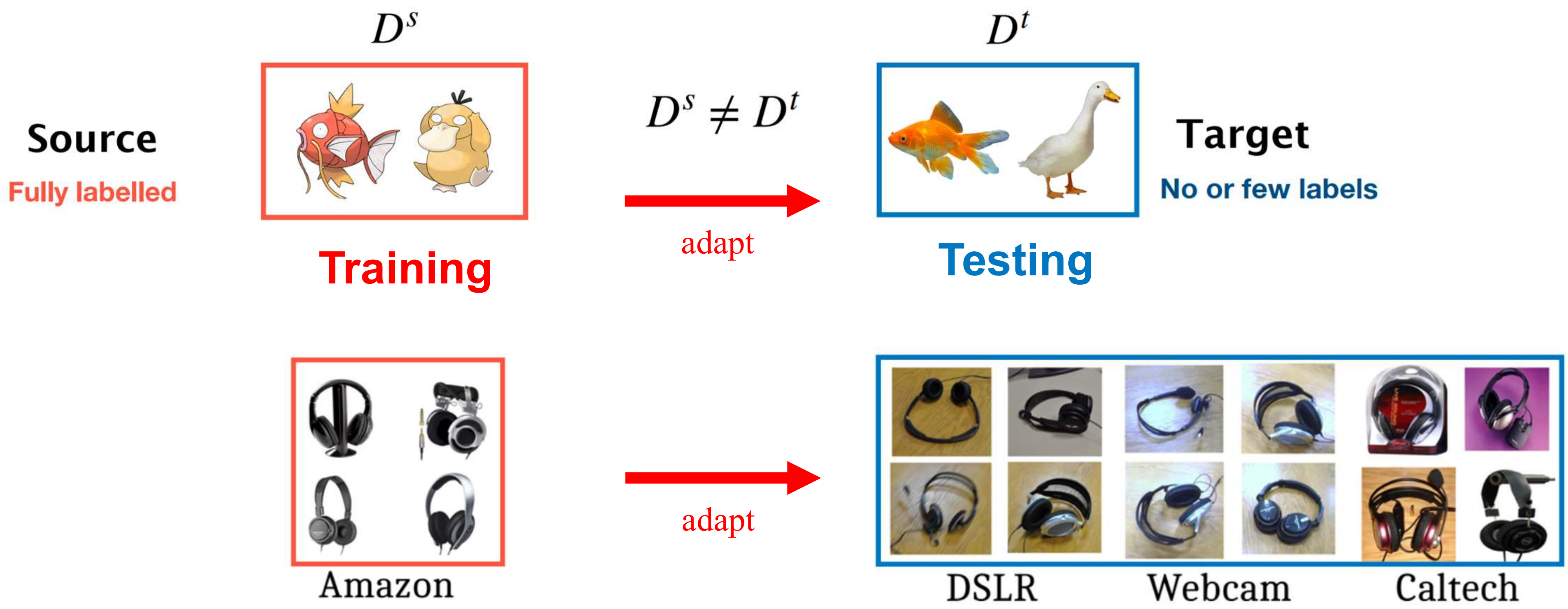
Intuitive Definition of Domain

Domain D



Slide credit: Chonghao Zhao

Domain Adaptation: Train on Source Test on Target



Slide credit: Chonghao Zhao

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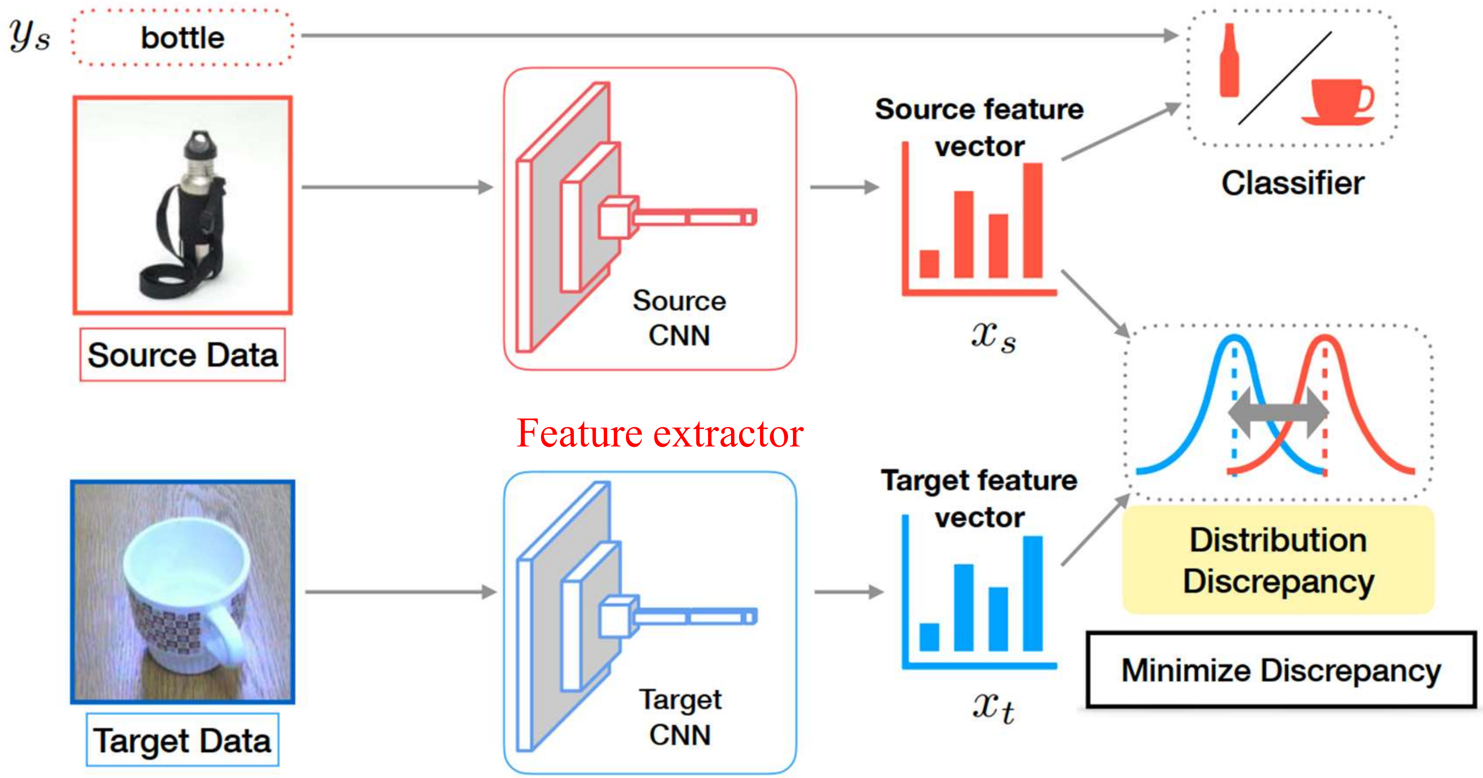
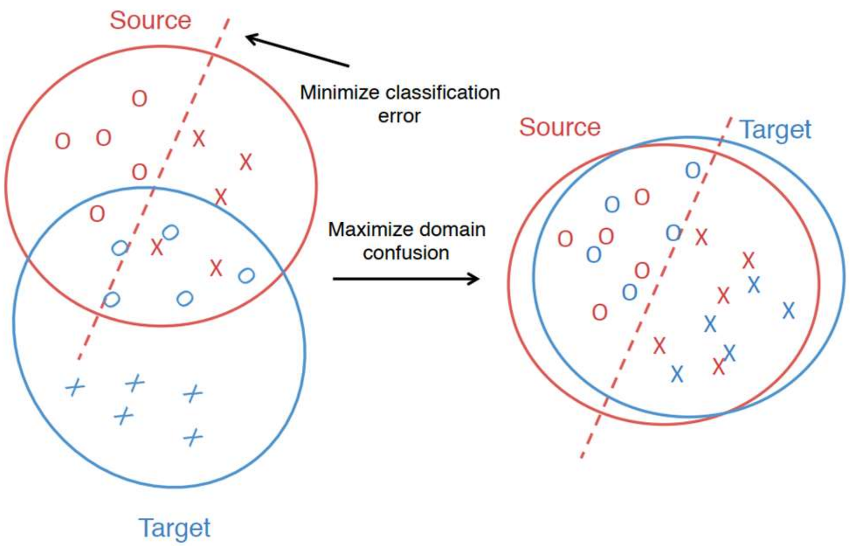
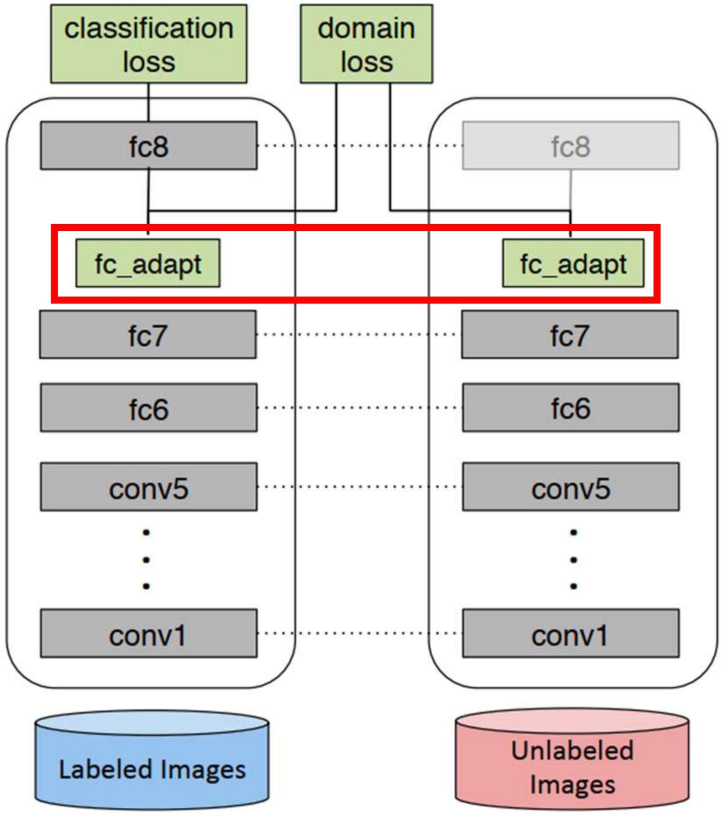
Discrepancy-based methods



Slide credit: Judy Hoffman

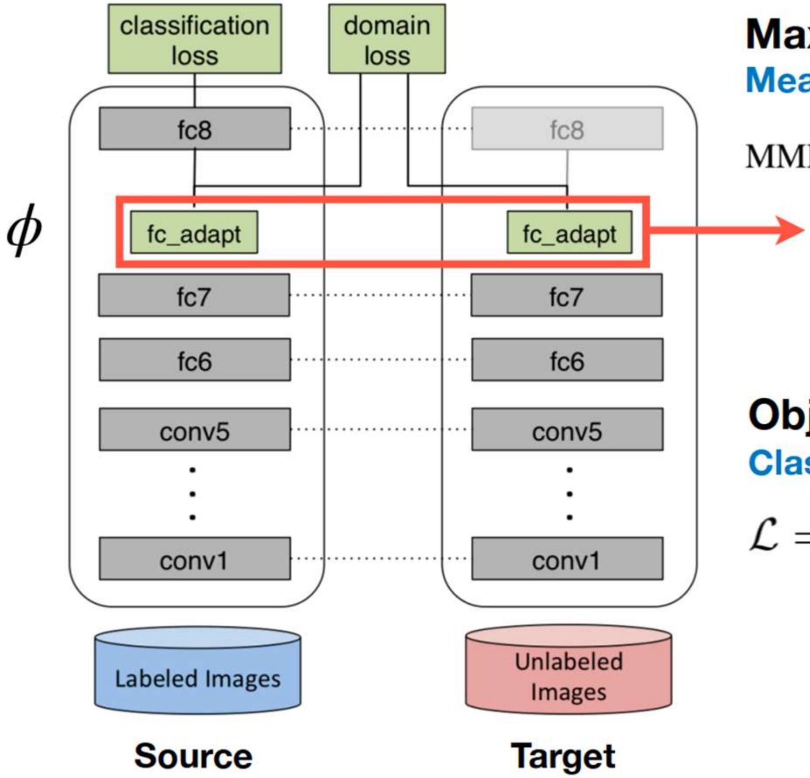
Deep Domain Confusion





[CoRR 2014] Deep Domain Confusion- Maximizing for Domain Invariance

MMD: Max Mean Discrepancy



Maximum Mean Discrepancy

Measuring distance between distributions

$$\mathrm{MMD}(X_S, X_T) = \left\| \frac{1}{|X_S|} \sum_{x_s \in X_S} \phi(x_s) - \frac{1}{|X_T|} \sum_{x_t \in X_T} \phi(x_t) \right\|$$

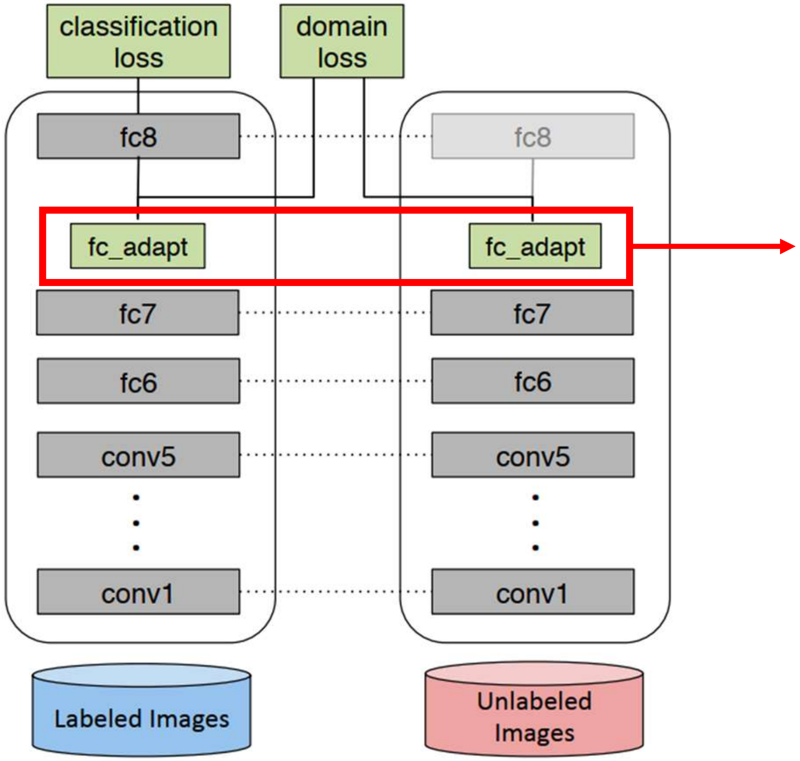
Objective Function

Classification + MMD

$$\mathcal{L} = \mathcal{L}_C(X_L, y) + \lambda \mathrm{MMD}^2(X_S, X_T)$$

Slide credit: Chonghao Zhao

Other Discrepancy-based methods



- CORAL: use 2nd order moments
- CMD： use even higher moments
- KL divergence:

$$KL(P,Q) = \sum_i P(i) log \frac{P(i)}{Q(i)}$$

- $\mathcal{H}$-divergence:

$$\widehat{d_A} = 2(1-2\epsilon)$$

- Wasserstein distance:

$$W(P_1, P_2) = \inf_{\gamma \sim \prod(P_1, P_2)} \mathbb{E}_{(x,y)\sim\gamma}[\|x-y\|]$$

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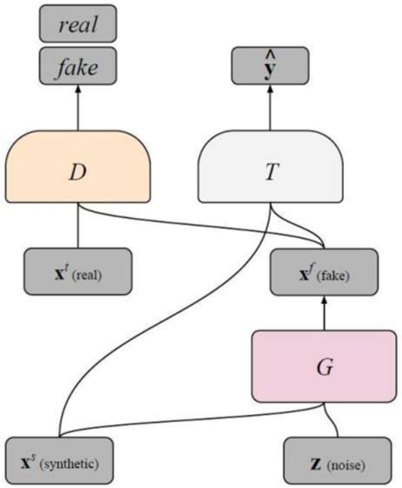
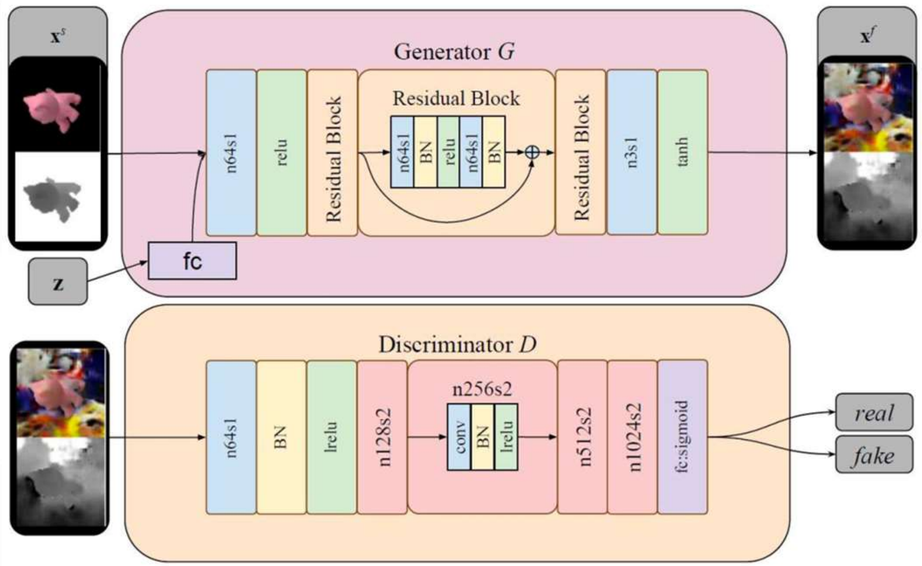
Generative Model: Pixel-level GANs

(a) Image examples from the Linemod dataset.

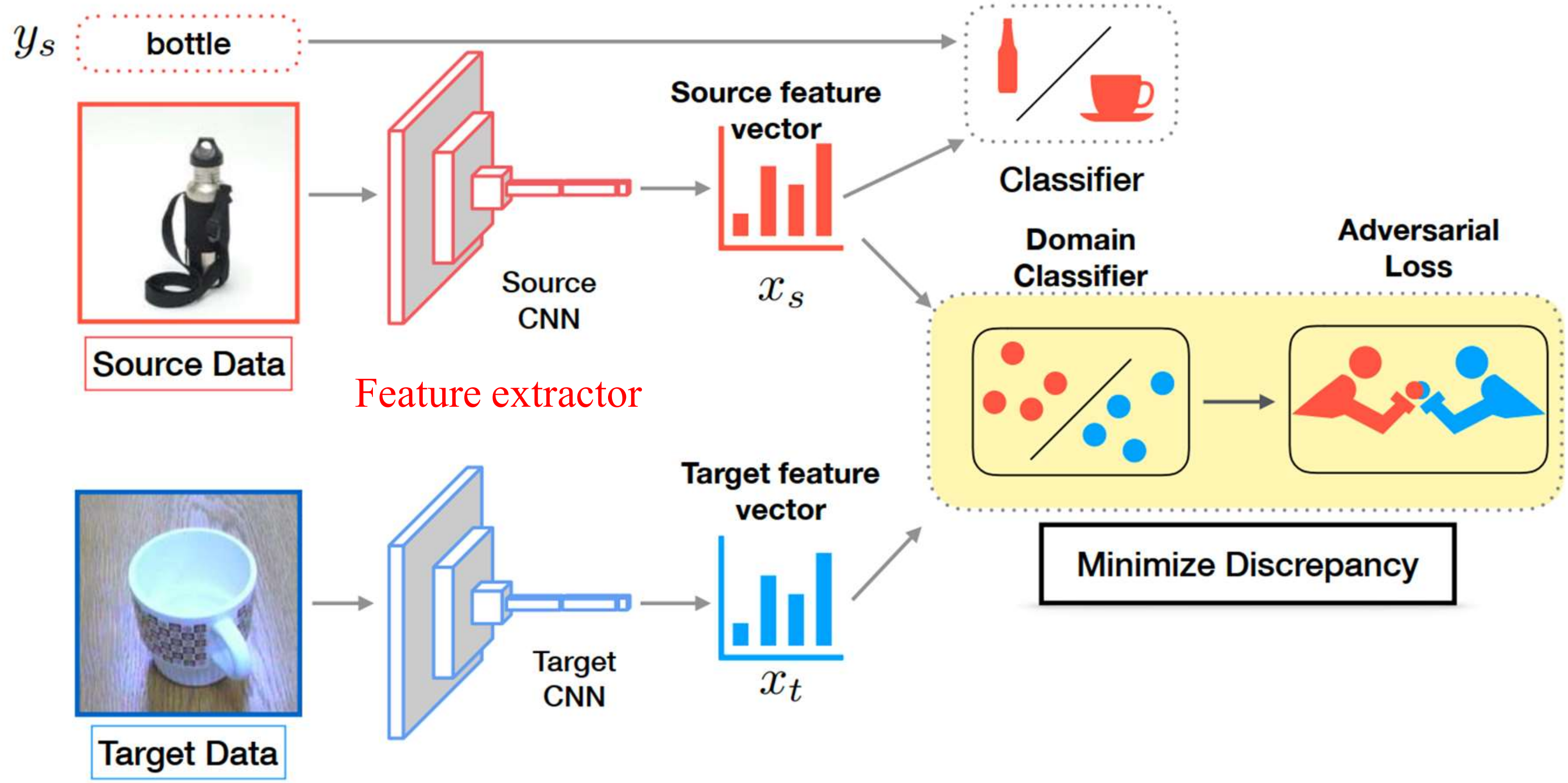
(b) Examples generated by our model, trained on Linemod.





[CVPR 2017] Unsupervised pixel-level domain adaptation with generative adversarial networks

Discriminative Model



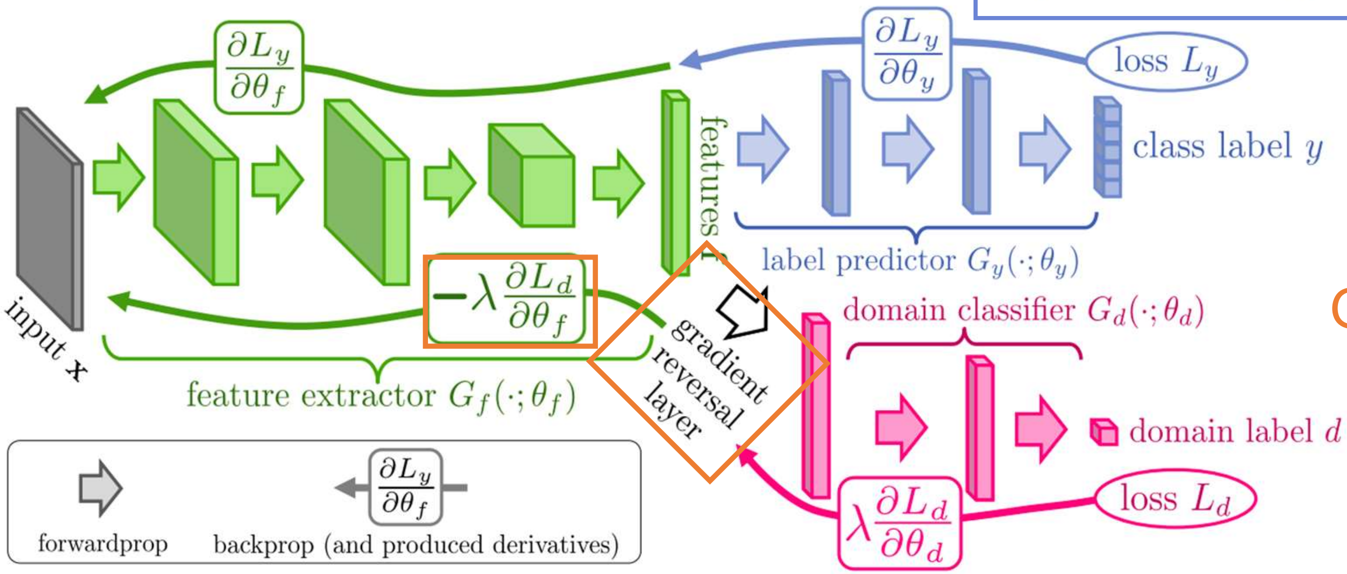
Slide credit: Judy Hoffman

DANN: Domain Adversarial Training of Neural Networks

$$G_f(\mathbf{x}; \mathbf{W}, \mathbf{b}) = \mathrm{sigm}\big(\mathbf{W}\mathbf{x} + \mathbf{b}\big)$$

$$G_y(G_f(\mathbf{x}); \mathbf{V}, \mathbf{c}) = \mathrm{softmax}\big(\mathbf{V}G_f(\mathbf{x}) + \mathbf{c}\big)$$

$$\mathcal{L}_y\big(G_y(G_f(\mathbf{x}_i)), y_i\big) = \log \frac{1}{G_y(G_f(\mathbf{x}))_{y_i}}$$



RevGrad

GRL

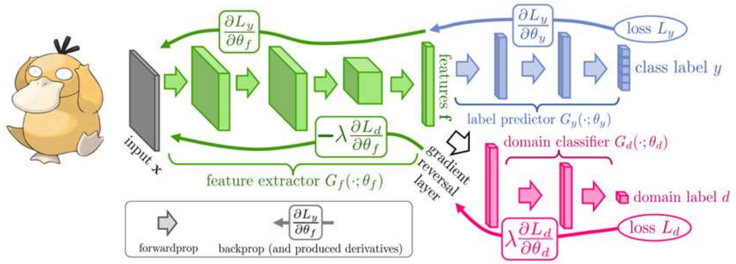
$$\mathcal{R}(\mathbf{x}) = \mathbf{x}$$
$$\frac{d\mathcal{R}}{d\mathbf{x}} = -\mathbf{I}$$

$$G_d(G_f(\mathbf{x}); \mathbf{u}, z) = \mathrm{sigm}\big(\mathbf{u}^\top G_f(\mathbf{x}) + z\big)$$

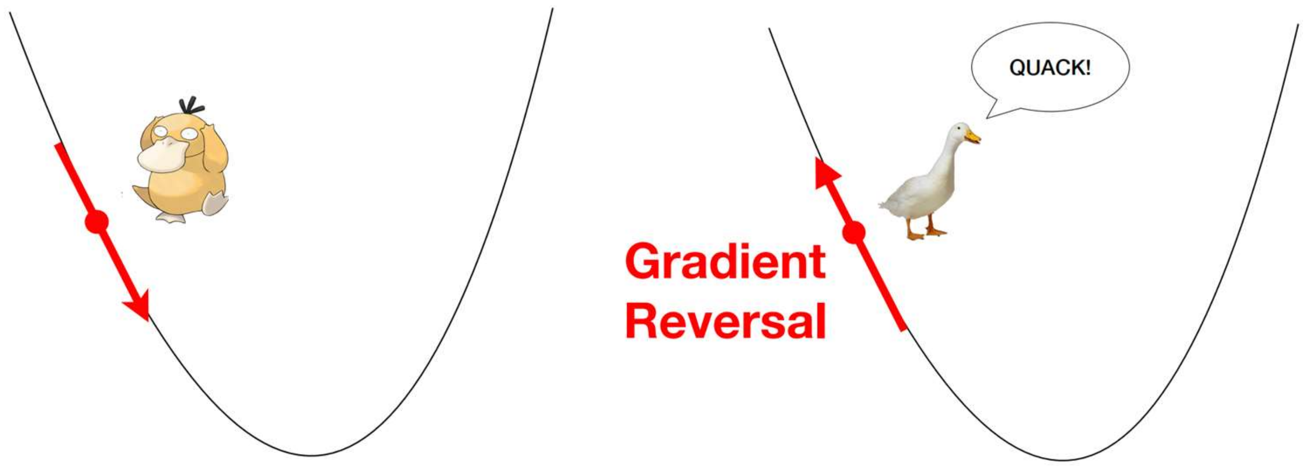
$$\mathcal{L}_d\big(G_d(G_f(\mathbf{x}_i)), d_i\big) = d_i \log \frac{1}{G_d(G_f(\mathbf{x}_i))} + (1-d_i) \log \frac{1}{1-G_d(G_f(\mathbf{x}_i))}$$

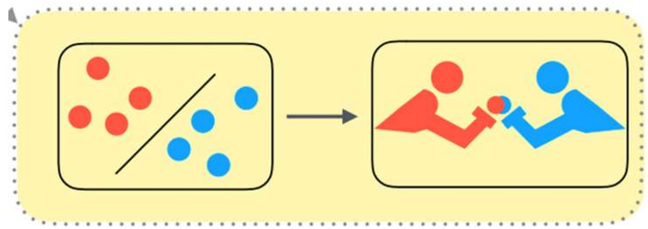
[JMLR 2016] Domain Adversarial Training of Neural Networks

RevGrad



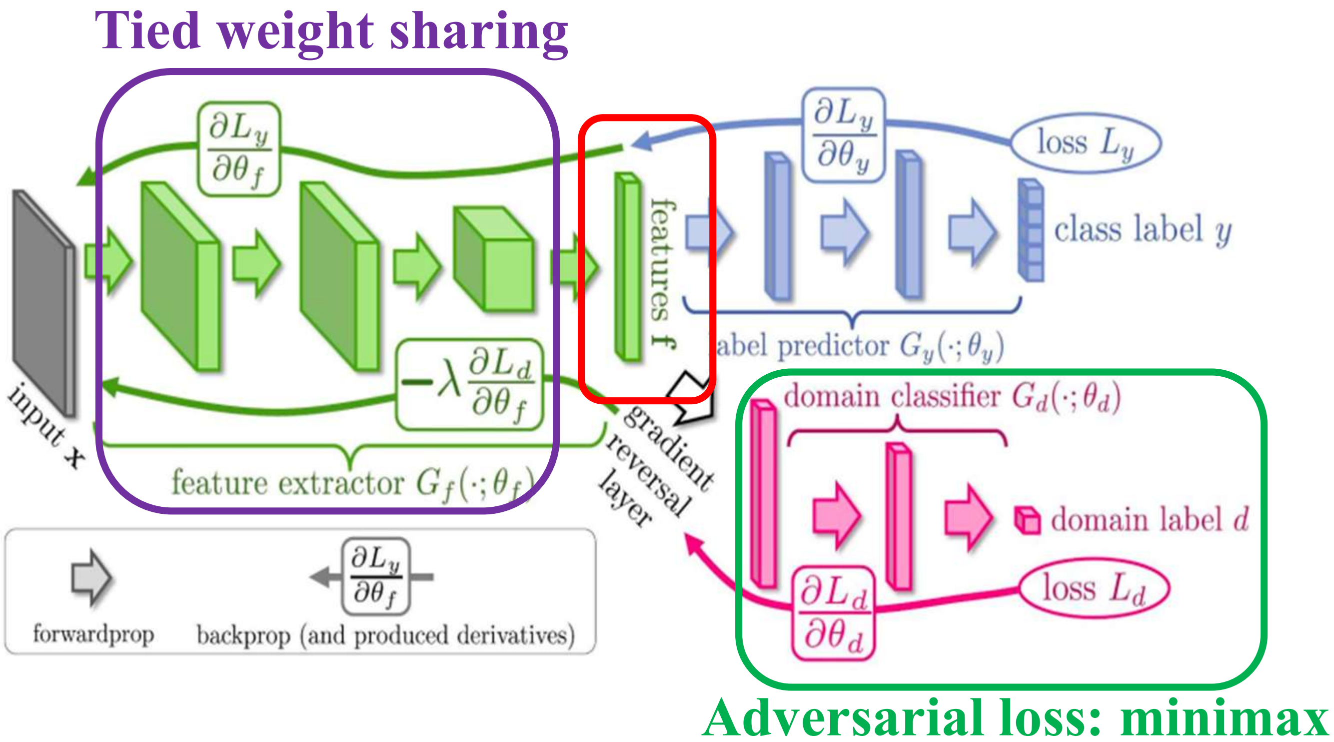
Loss of domain classifier





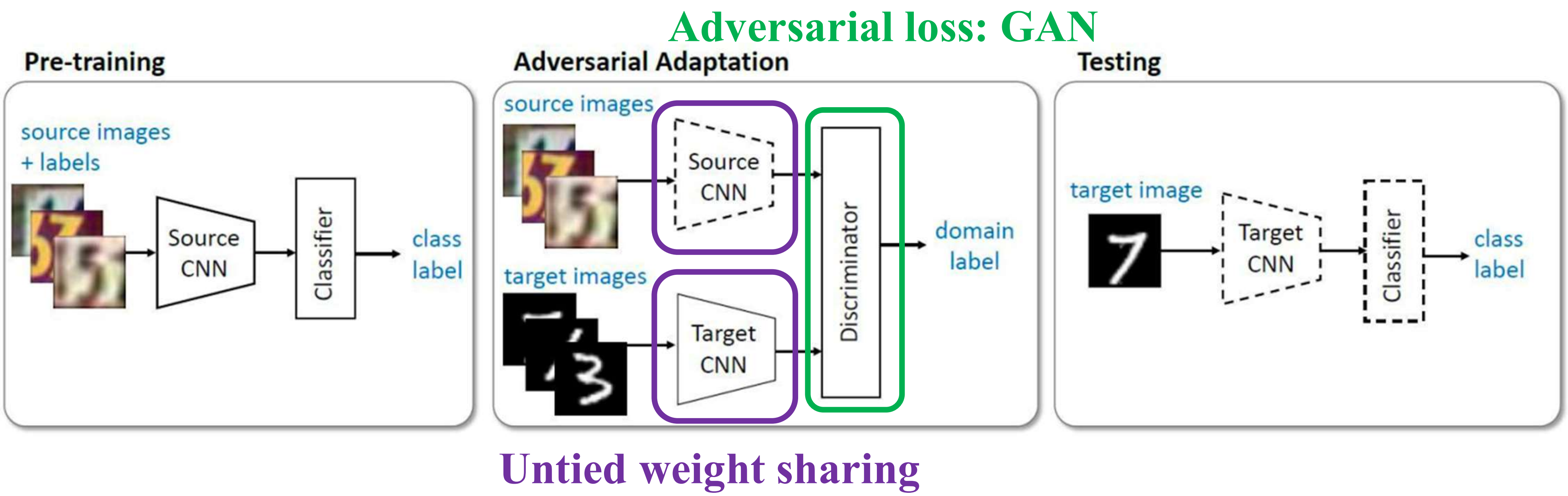
Slide credit: Chonghao Zhao

DANN: Domain Adversarial Training of Neural Networks



[JMLR 2016] Domain Adversarial Training of Neural Networks

ADDA: Adversarial Discriminative Domain Adaptation



[CVPR 2017] Adversarial Discriminative Domain Adaptation

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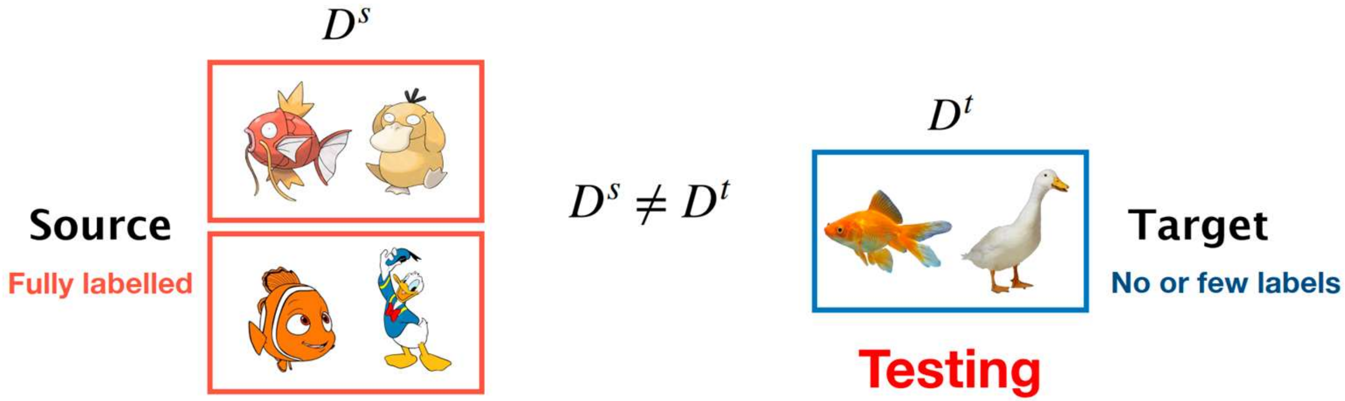
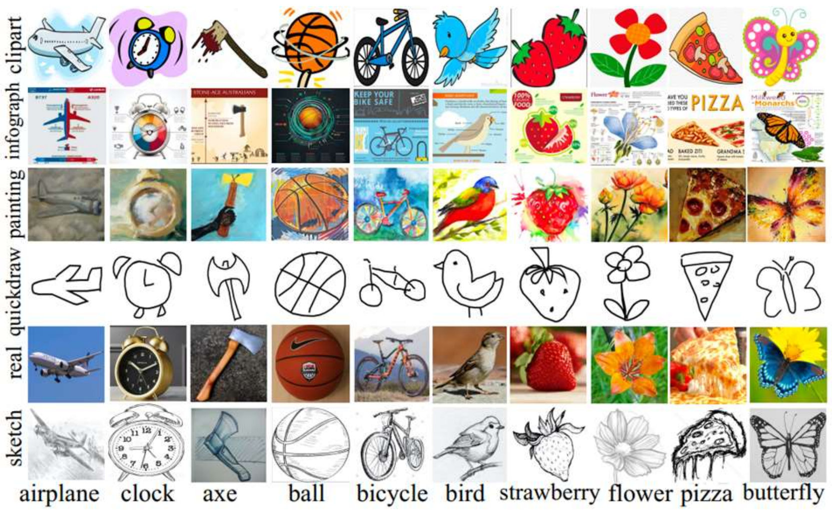
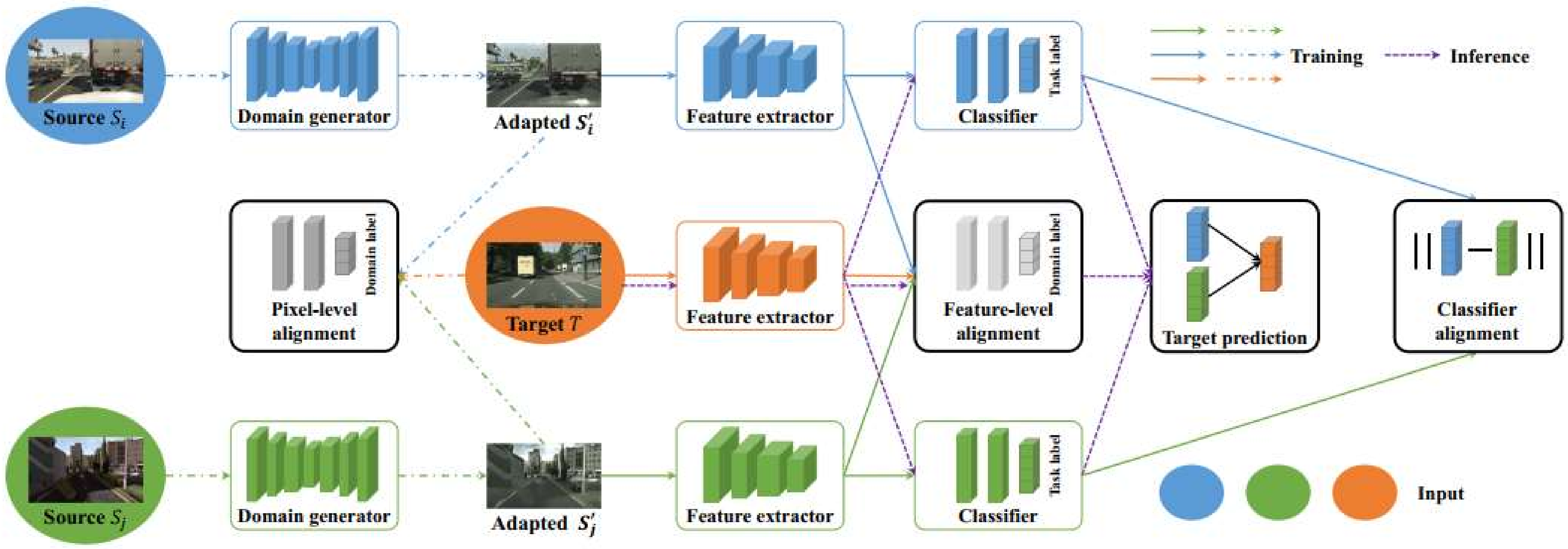
Multi-source Domain Adaptation





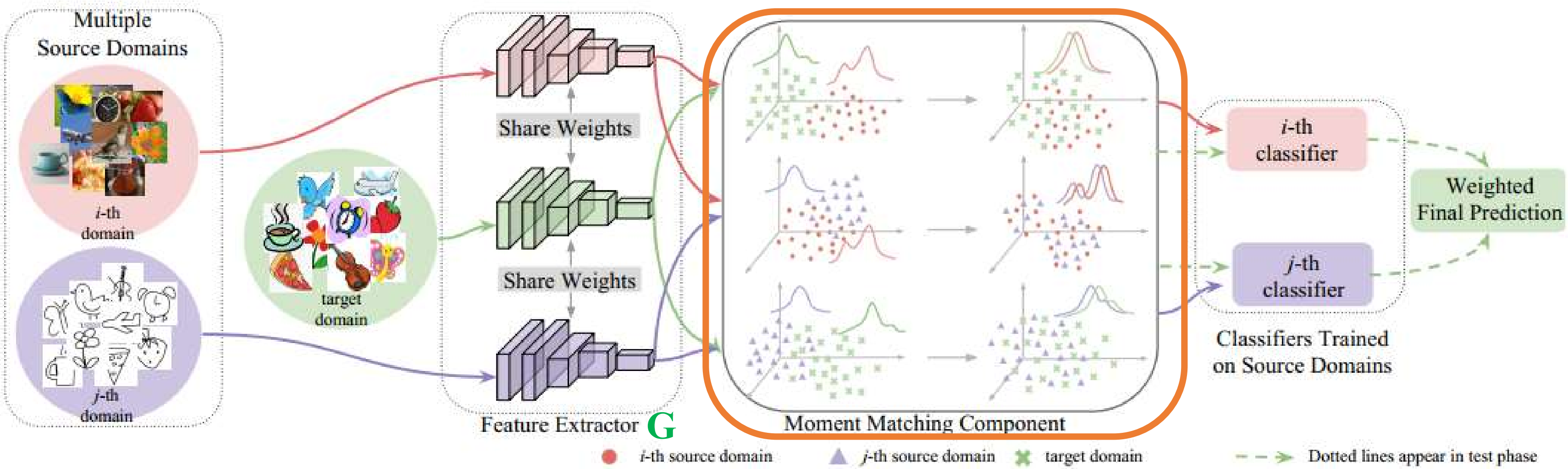
Multi-source Domain Adaptation



[arXiv 2020] Multi-source Domain Adaptation in the Deep Learning Era: A Systematic Survey

M3SDA: Moment Matching for Multi-Source Domain Adaptation

minimizes the moment-related distance



cross-entropy loss

$$\min_{G,\mathcal{C}} \sum_{i=1}^{N} \mathcal{L}_{\mathcal{D}_i} + \boxed{\lambda \min_{G} MD^2(\mathcal{D}_S, \mathcal{D}_T)}$$

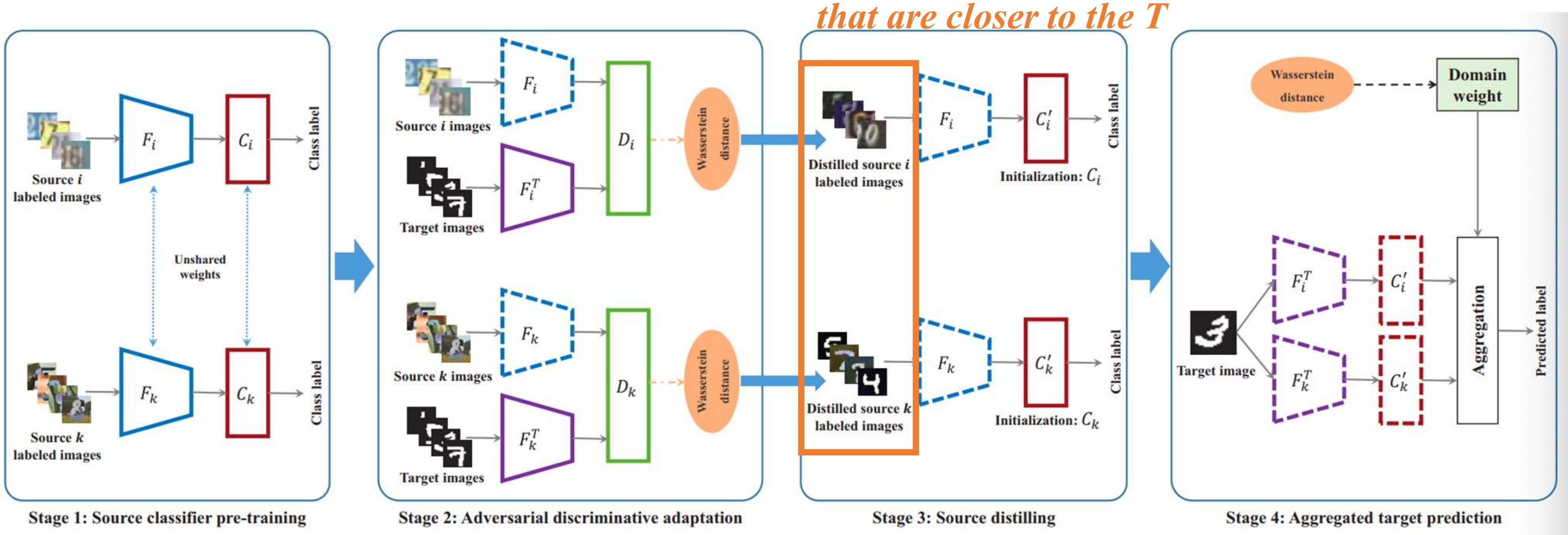
Feature alignment

$$\boxed{\begin{aligned} MD^2(\mathcal{D}_S, \mathcal{D}_T) = \sum_{k=1}^{2} \Big(\frac{1}{N} \sum_{i=1}^{N} \|\mathbb{E}(\mathbf{X}_i^k) - \mathbb{E}(\mathbf{X}_T^k)\|_2 \\ + \binom{N}{2}^{-1} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \|\mathbb{E}(\mathbf{X}_i^k) - \mathbb{E}(\mathbf{X}_j^k)\|_2 \Big). \end{aligned}}$$

[ICCV 2019] Moment Matching for Multi-Source Domain Adaptation

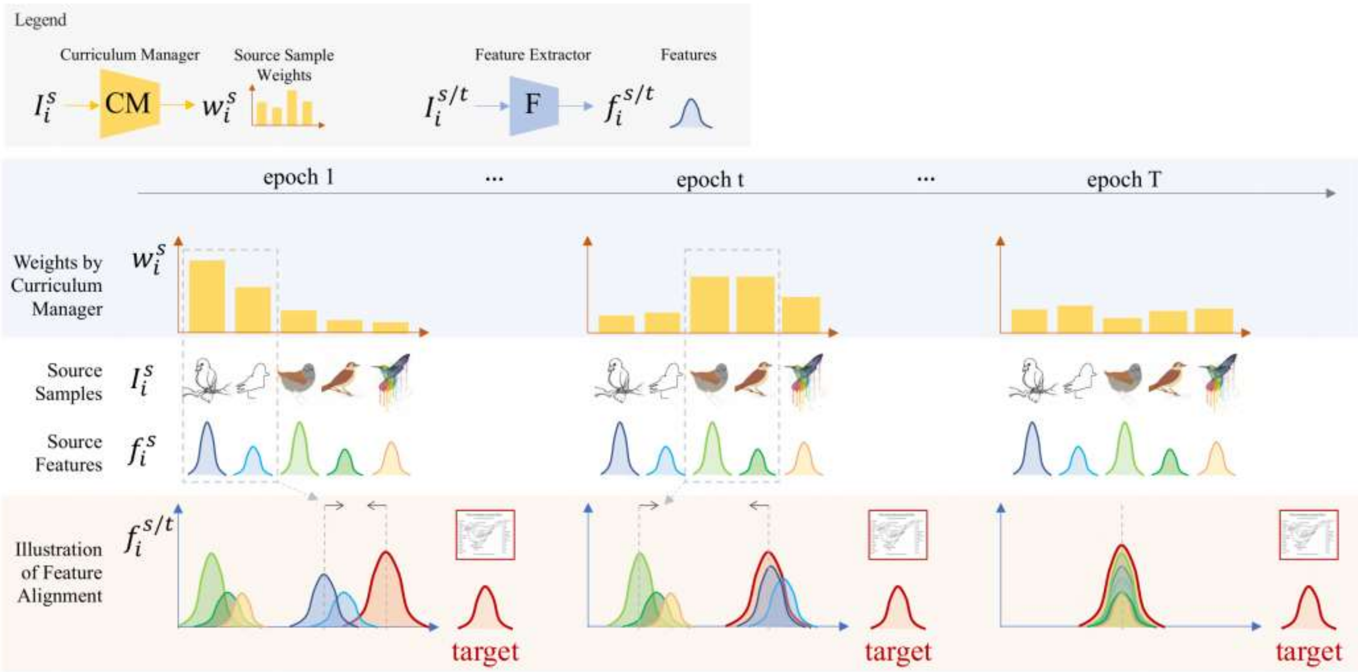
MDDA: Multi-source Distilling Domain Adaptation

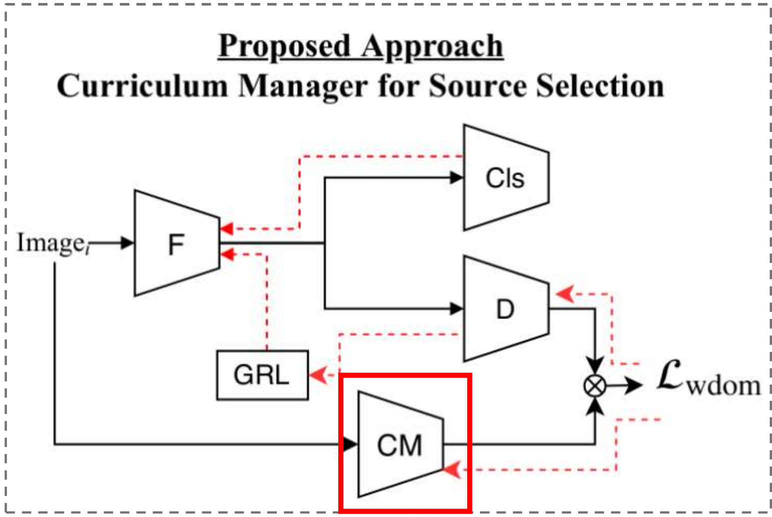
Selected S samples that are closer to the T



[AAAI 2020] Multi-source Distilling Domain Adaptation

CMSS: Curriculum Manager for Source Selection





Generate weight vector of training samples

[ECCV 2020] Curriculum Manager for Source Selection in Multi-Source Domain Adaptation

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What is Universal Domain Adaptation?

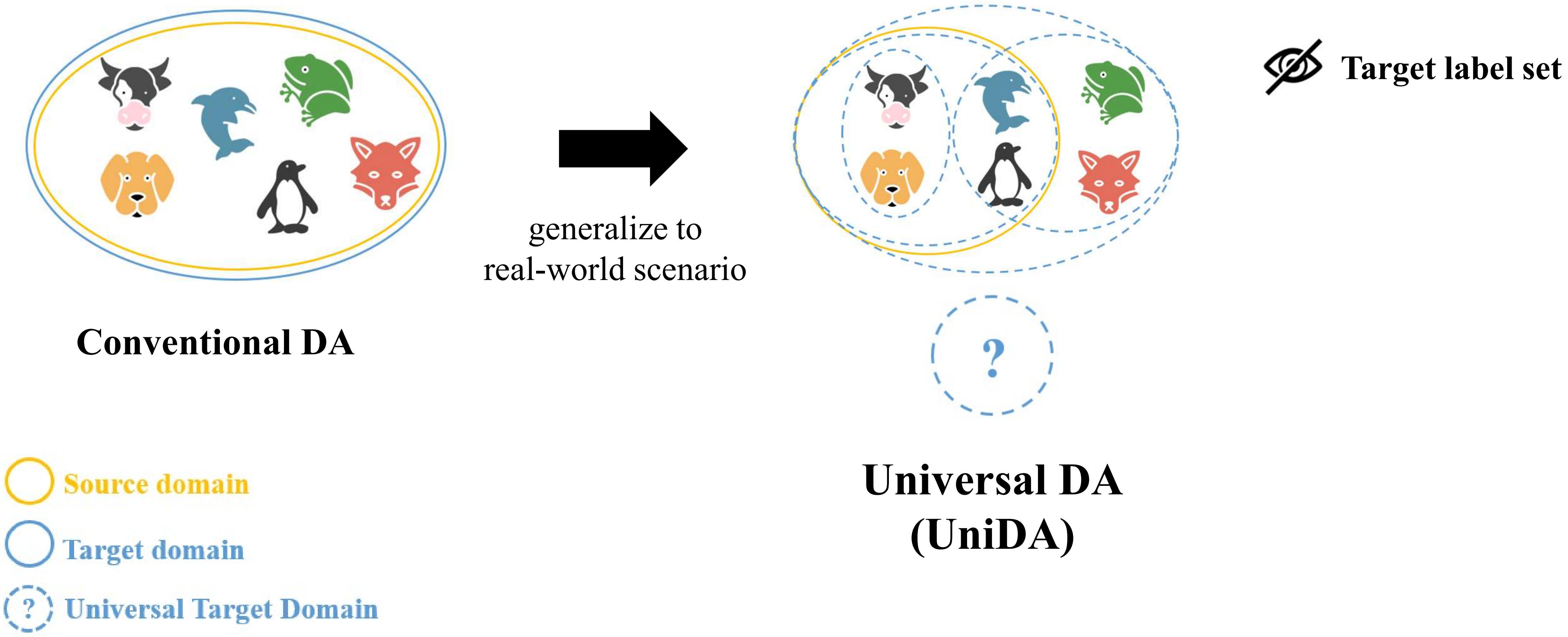
Conventional DA

Source domain

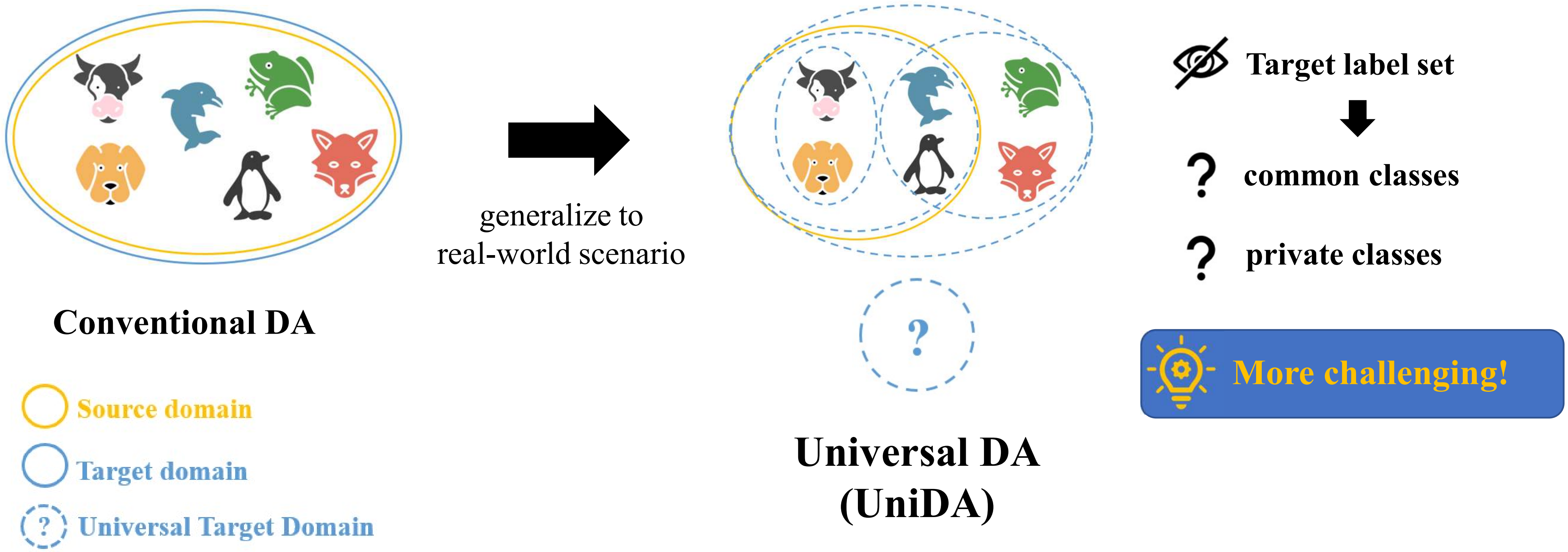
Target domain

? Universal Target Domain

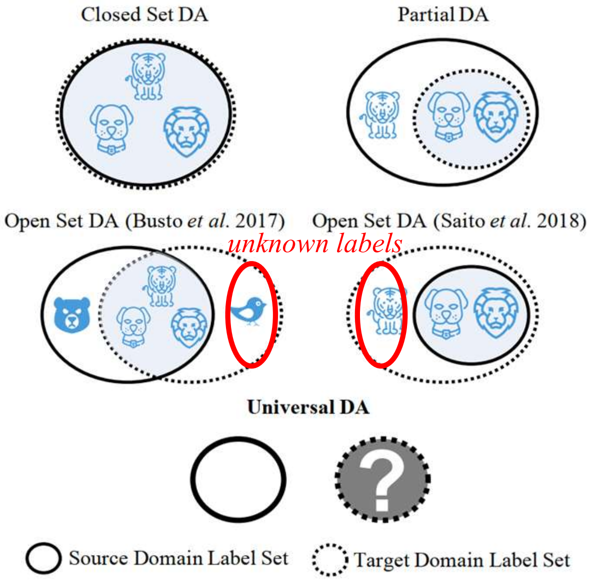
What is Universal Domain Adaptation?

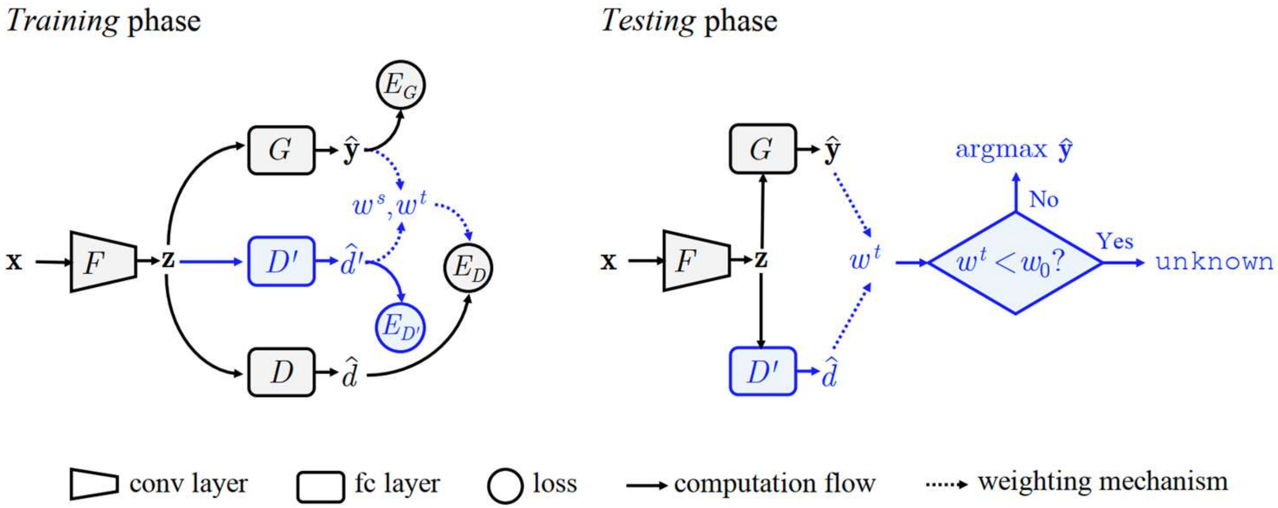


What is Universal Domain Adaptation?



UAN: Universal Adaptation Network





$$E_G = \mathbb{E}_{(\mathbf{x},\mathbf{y})\sim p} L\left(\mathbf{y}, G(F(\mathbf{x}))\right)$$

$$\begin{aligned} E_{D'} = & -\mathbb{E}_{\mathbf{x}\sim p} \log D'\left(F\left(\mathbf{x}\right)\right) \\ & -\mathbb{E}_{\mathbf{x}\sim q} \log\left(1 - D'\left(F\left(\mathbf{x}\right)\right)\right) \end{aligned}$$

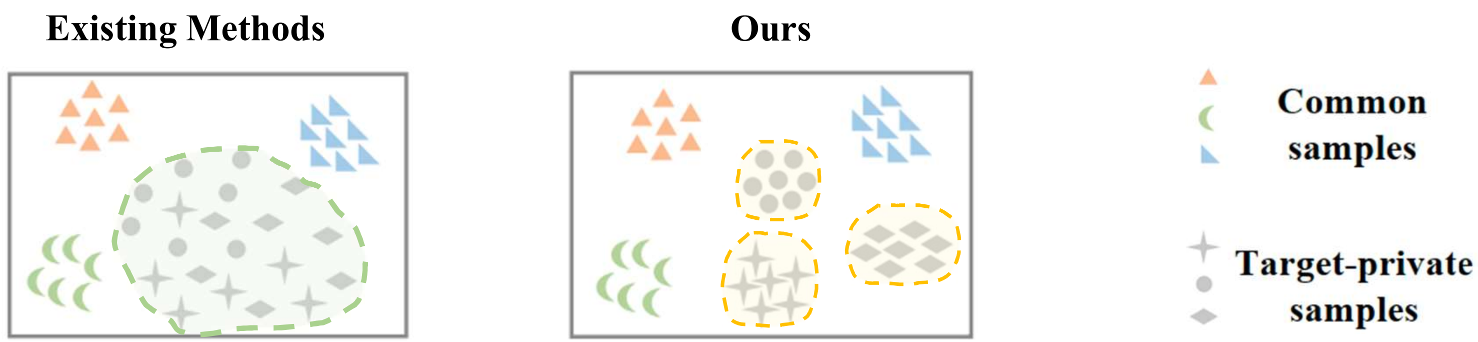
$$\begin{aligned} E_D = & -\mathbb{E}_{\mathbf{x}\sim p} w^s(\mathbf{x}) \log D\left(F\left(\mathbf{x}\right)\right) \\ & -\mathbb{E}_{\mathbf{x}\sim q} w^t(\mathbf{x}) \log\left(1 - D\left(F\left(\mathbf{x}\right)\right)\right) \end{aligned}$$

$$\max_{D} \min_{F,G} E_G - \lambda E_D$$

$$\min_{D'} E_{D'}$$

[CVPR 2019] Universal Domain Adaptation

Existing Methods

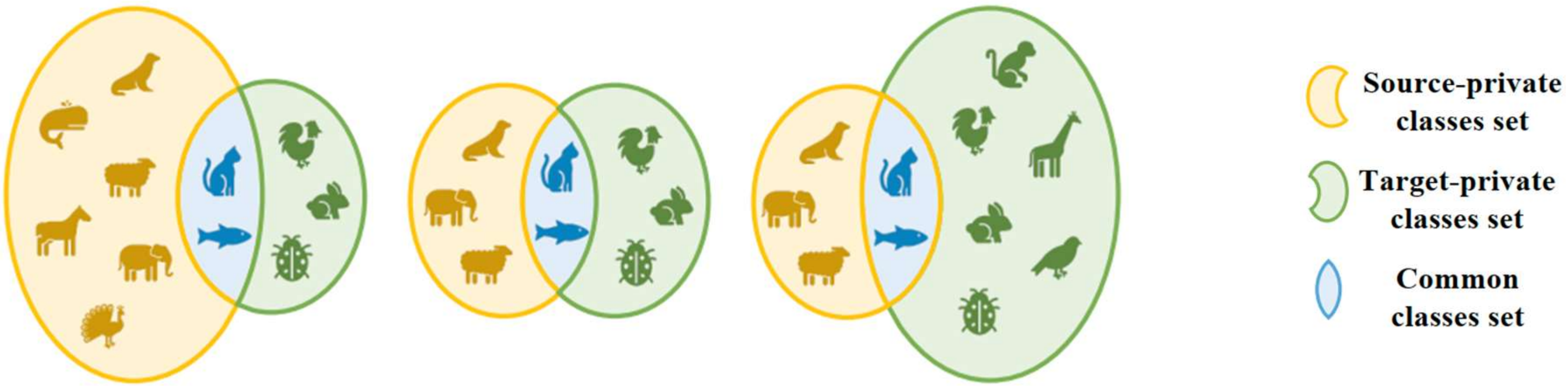


😥 **ignore the intrinsic structure of target domain**

😥 **deteriorate target representation and model performance**

😥 **learn a not well-generalized model to target domain**

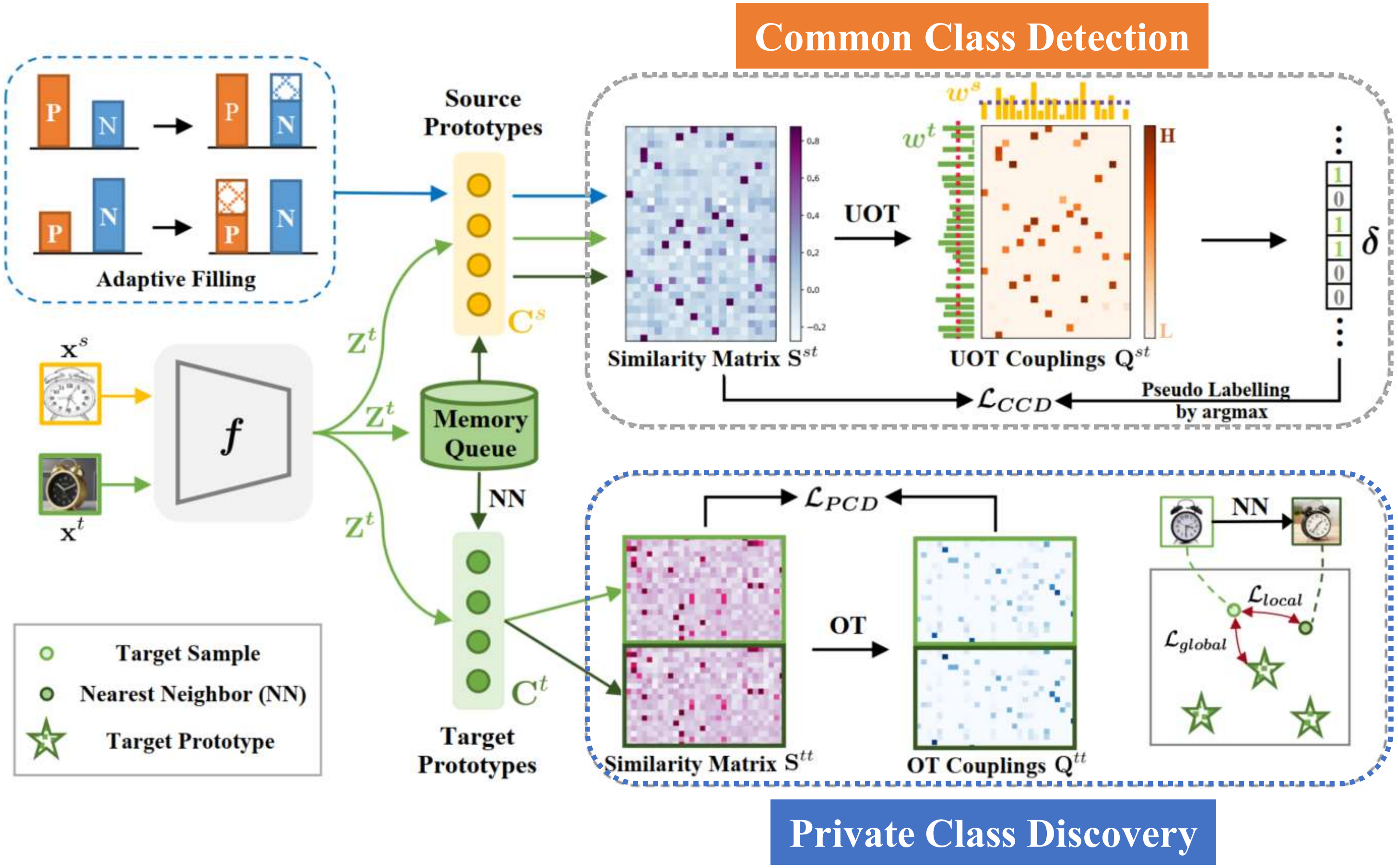
Existing Methods



diverse ratios of common categories

😥 **very sensitive to threshold values**

Unified OT Framework for UniDA



$$\mathcal{L}_{overall} = \mathcal{L}_{cls} + \lambda(\mathcal{L}_{CCD} + \mathcal{L}_{PCD})$$

【【VALSE论文速览-109期】基于统一最优运输框架的通用域适应方法】 https://www.bilibili.com/video/BV1NM411L7BB

Questions?