NEURAL INFORMATION PROCESSING SYSTEMS

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Unified Optimal Transport Framework for Universal Domain Adaptation




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NeurIPS 2022

October 21, 2022

Page: https://changwxx.github.io/UniOT-webpage/

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What is Universal Domain Adaptation?

Conventional DA

Source domain

Target domain

Universal Target Domain

What is Universal Domain Adaptation?

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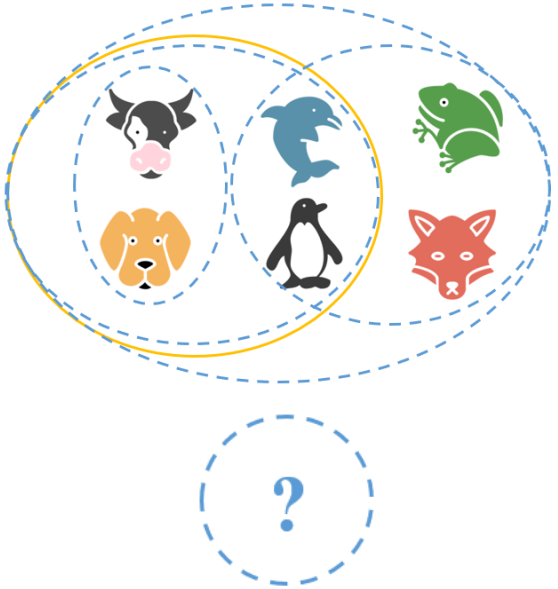
Conventional DA

generalize to
real-world scenario



Universal DA
(UniDA)

Target label set

Source domain

Target domain

Universal Target Domain

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What is Universal Domain Adaptation?

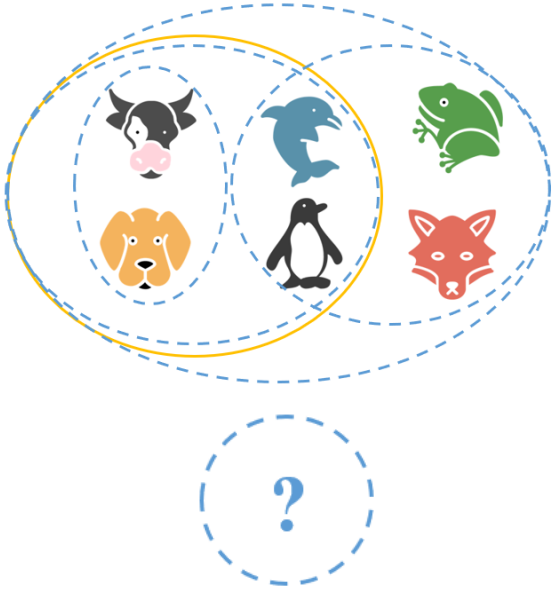
Conventional DA

Source domain

Target domain

Universal Target Domain

generalize to
real-world scenario



Universal DA (UniDA)

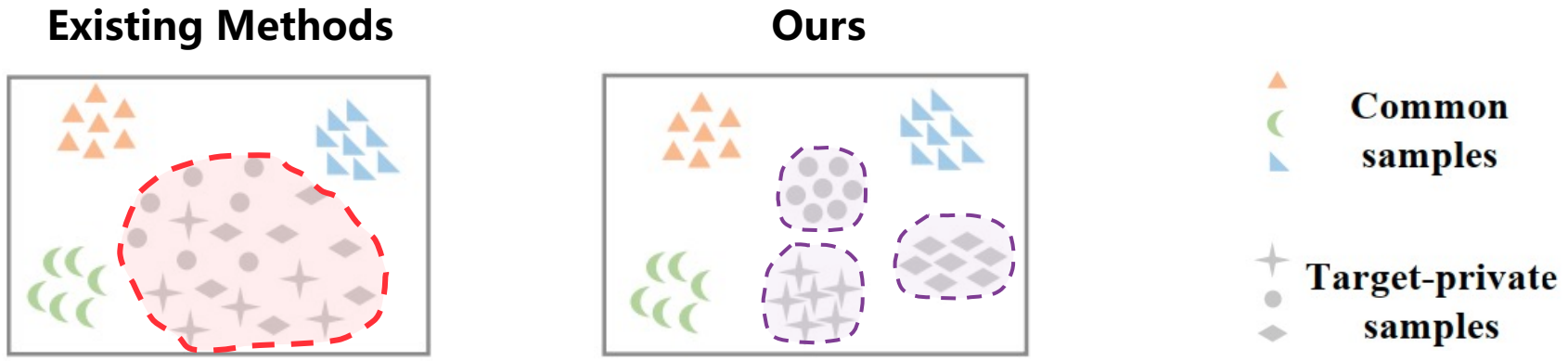
Target label set

? common classes

? private classes

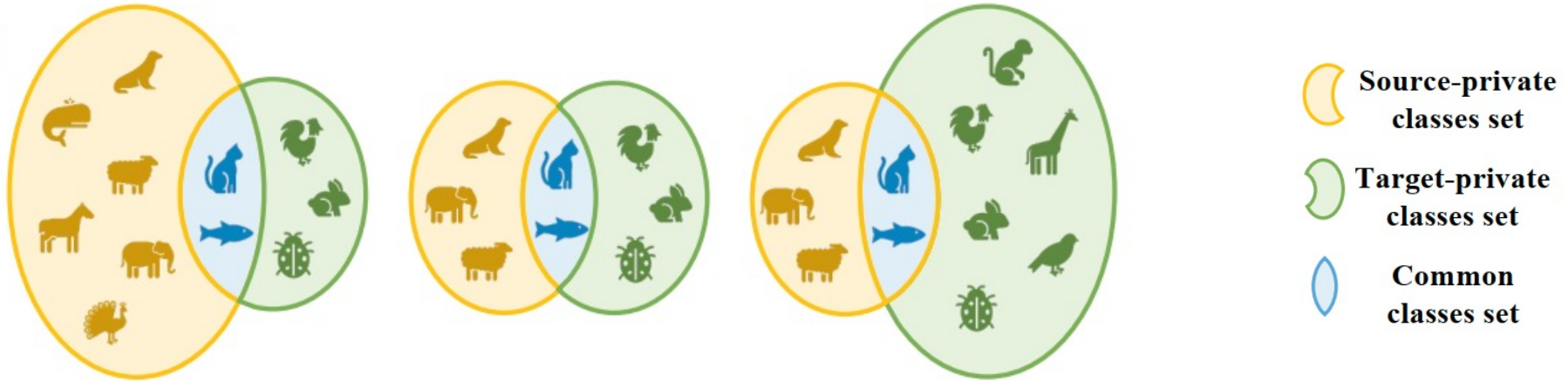
More challenging!

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**

Optimal Transport (OT)

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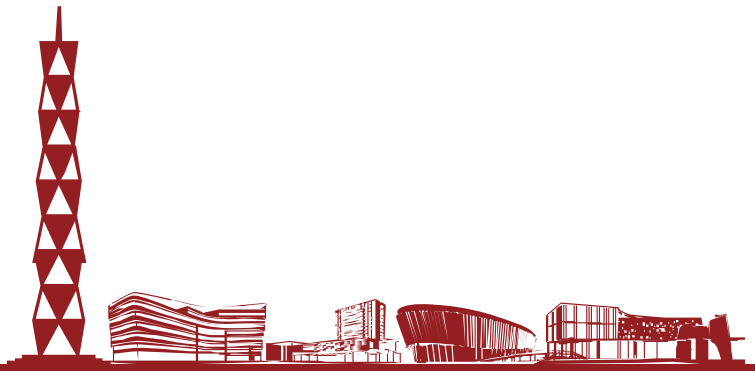
Common Class Detection
&
Private Class Discovery



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Optimal Transport (OT)

Common Class Detection
&
Private Class Discovery

distribution transportation problems

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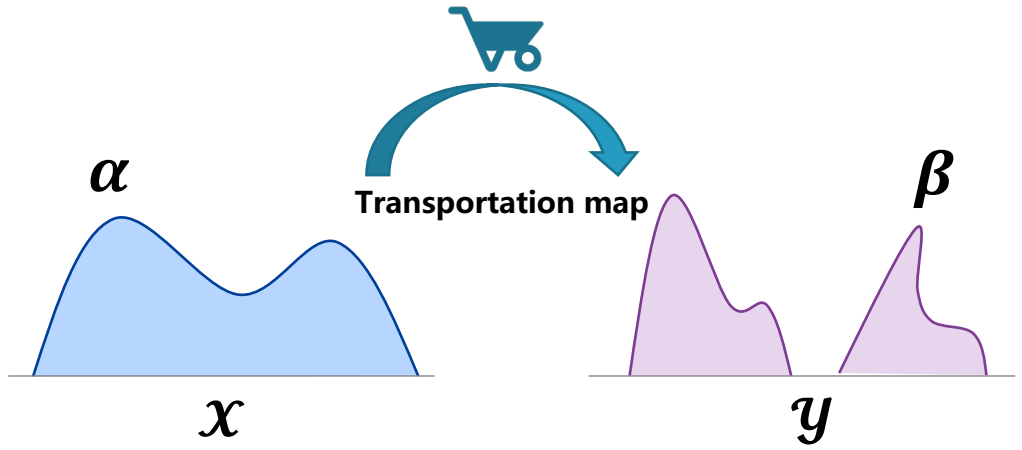

OT is a promising optimization problem to seek an efficient solution for transporting one distribution to another.

Unified OT Framework for UniDA

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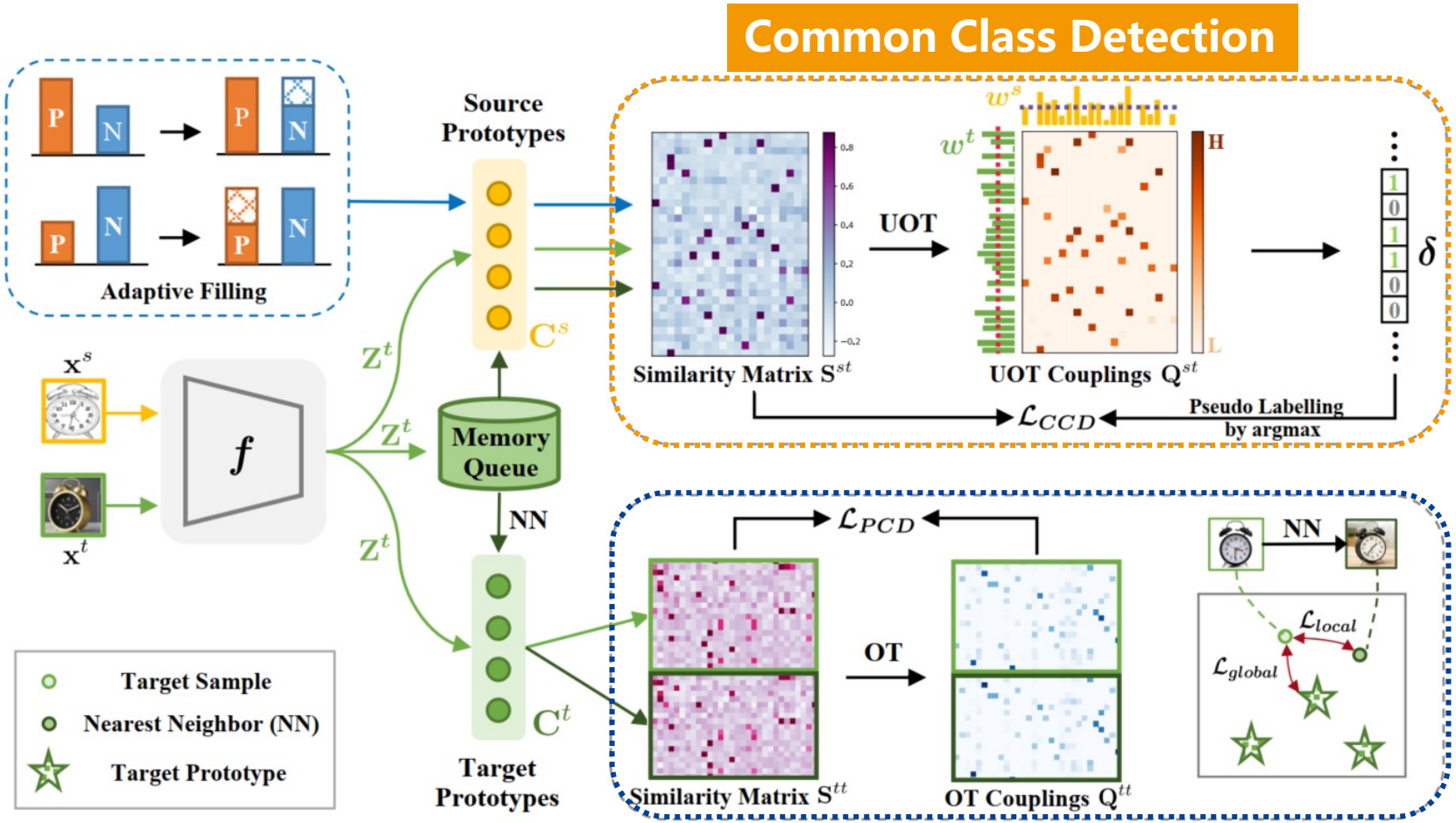

$$\mathcal{L}_{overall} = \mathcal{L}_{cls} + \lambda(\mathcal{L}_{CCD} + \mathcal{L}_{PCD})$$

Inter-domain Partial Alignment for Common Class Detection

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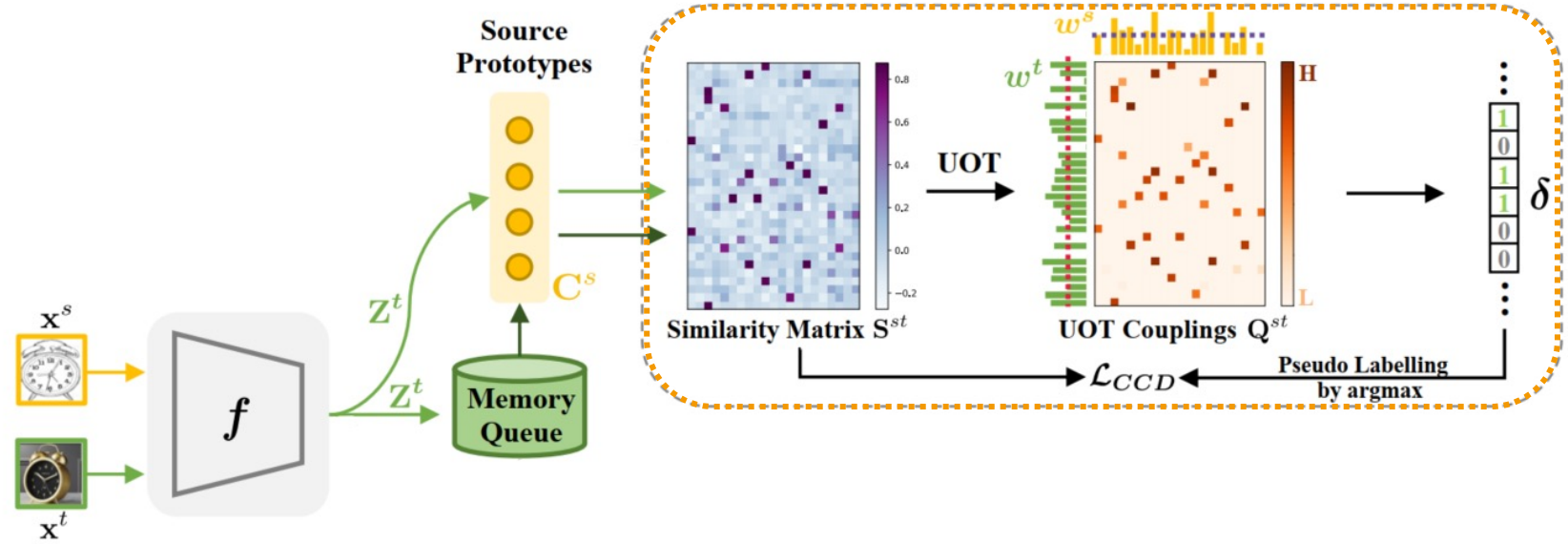
Common Class Detection



Target sample confidence score based on UOT couplings

$$w_i^t = \max(\{\bar{\mathbf{Q}}_{i,1}^{st}, \bar{\mathbf{Q}}_{i,2}^{st}, \cdots, \bar{\mathbf{Q}}_{i,|\mathcal{C}_s|}^{st}\})$$

Source prototype confidence score

$$w_j^s = \sum_{i=1}^{B} \bar{\mathbf{Q}}_{i,j}^{st}$$

Top confident target samples detected by statistics mean

$$\delta_i = \begin{cases} 1, & w_i^t \geq \frac{1}{B} \text{ and } w_{\hat{y}_i^t}^s \geq \frac{1}{|\mathcal{C}_s|} \\ 0, & \text{otherwise} \end{cases}$$

$$\mathcal{L}_{CCD} = \frac{\sum_{i=1}^{B} \delta_i \cdot \mathcal{L}_{CE}(\mathbf{z}_i^t, \hat{y}_i^t)}{\sum_{i=1}^{B} \delta_i}$$

Adaptive filling for unbalanced proportion of positive and negative

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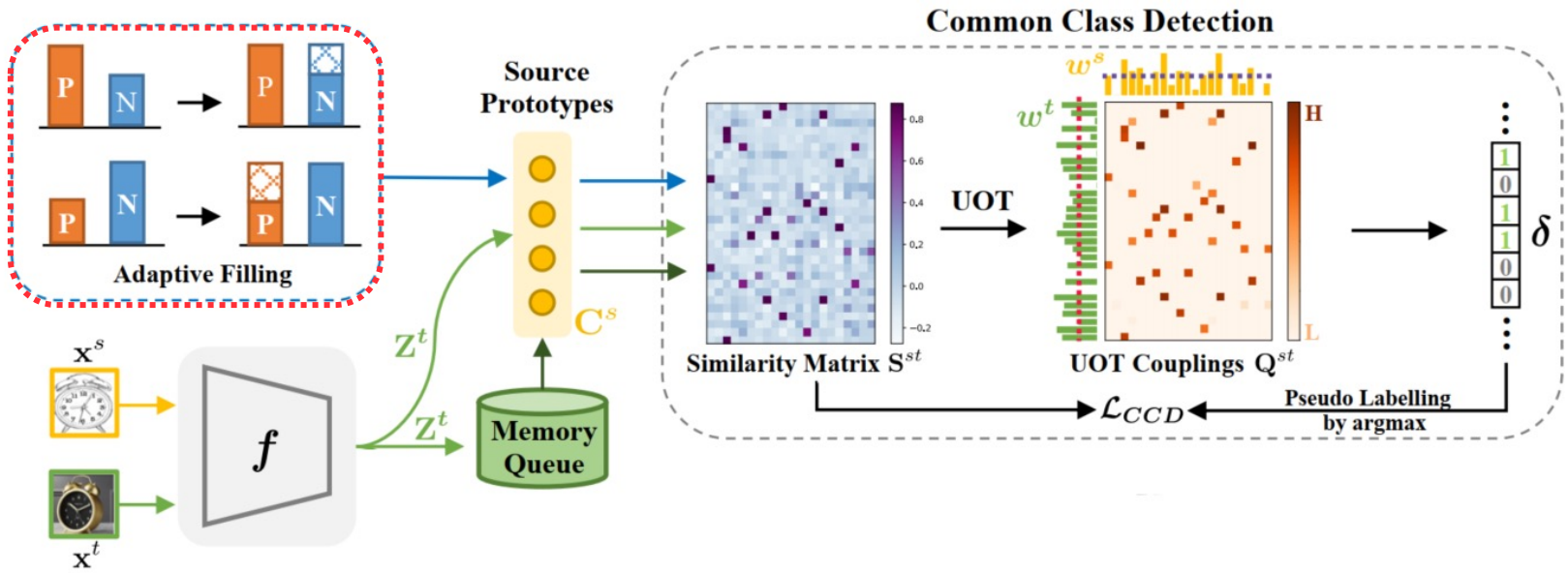
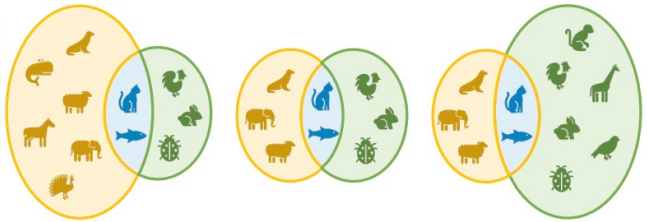
Adaptive Filling





to deal with diverse ratios of common categories

- **Negative filling**: synthesize fake private feature by mixing up target feature and its farthest source prototypes evenly
- **Positive filling**: reuse filtered confident features obtained by unfilled CCD

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Intra-domain Representation Learning for Private Class Discovery

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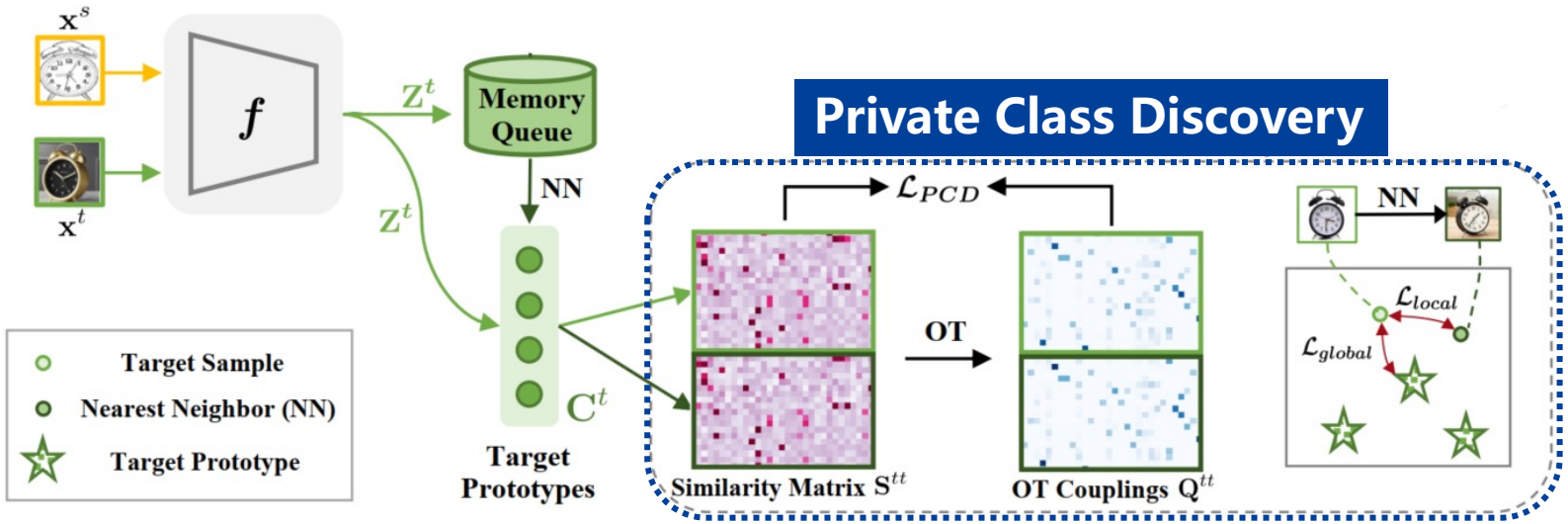

global discrimination of clusters

$$\mathcal{L}_{global} = \frac{1}{B}\sum_{i=1}^{B}\ell(\tilde{\mathbf{q}}_i^{tt}, \mathbf{z}_i^t)$$

local consistency of samples

$$\mathcal{L}_{local} = \frac{1}{2B}\sum_{i=1}^{B}\left[\ell(\tilde{\mathbf{q}}_i^{tt}, \mathbf{z}_i^t) + \ell(\tilde{\mathbf{q}}_i^{tt}, \tilde{\mathbf{z}}_i^t)\right]$$

$$\mathcal{L}_{PCD} = \frac{1}{2}(\mathcal{L}_{global} + \mathcal{L}_{local})$$

Experimental Settings

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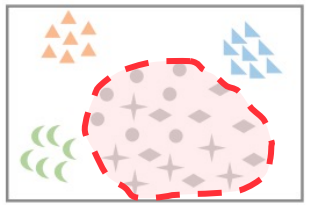
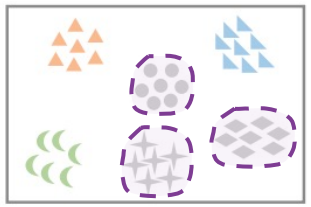
- A new evaluation metric H^3−score:
  - accuracy on common class
  - accuracy on unknown class
  - Normalized Mutual Information (NMI) for target-private clusters

	UniDA w/o PCD	UniDA w/ PCD
		
H-score	80% 👍	80% 👍
H^3−score	30% 👎	80% 👍

$$\mathrm{H}^3\text{−score} = \frac{3}{\frac{1}{a_c} + \frac{1}{a_{\bar{c}}} + \frac{1}{\mathrm{NMI}}}$$

Comparison with state-of-the-arts

H-score(%) on **Office** and **DomainNet**.

	Office							DomainNet						
	A2D	A2W	D2A	D2W	W2A	W2D	Avg	P2R	R2P	P2S	S2P	R2S	S2R	Avg
ResNet[21]	49.78	47.92	48.48	54.94	48.96	55.60	50.94	30.06	28.34	26.95	26.95	26.89	29.74	28.15
DANN[19]	50.18	48.82	47.69	52.73	49.33	54.87	50.60	31.18	29.33	27.84	27.84	27.77	30.84	29.13
RTN[26]	50.18	50.21	47.65	54.68	49.28	55.24	51.21	32.27	30.29	28.71	28.71	28.63	31.90	30.08
IWAN[41]	50.64	50.13	49.65	54.06	49.79	55.44	51.62	35.38	33.02	31.15	31.15	31.06	34.94	32.78
PADA[5]	50.00	49.65	42.87	52.62	49.17	55.60	49.98	28.92	27.32	26.03	26.03	25.97	28.62	27.15
ATI[3]	50.48	48.58	48.48	55.01	48.98	55.45	51.16	32.59	30.57	28.96	28.96	28.89	32.21	30.36
OSBP[34]	51.14	50.23	49.75	55.53	50.16	57.20	52.34	33.60	33.03	30.55	30.53	30.61	33.65	32.00
UAN[40]	59.68	58.61	60.11	70.62	60.34	71.42	63.46	41.85	43.59	39.06	38.95	38.73	43.69	40.98
CMU[18]	68.11	67.33	71.42	79.32	72.23	80.42	73.14	50.78	**52.16**	45.12	44.82	45.64	50.97	48.25
DANCE‡[33]	72.64	62.43	63.27	76.29	57.37	82.79	66.62	-	-	-	-	-	-	-
DCC[24]	**88.50**	78.54	70.18	79.29	75.87	88.58	80.16	56.90	50.25	43.66	44.92	43.31	56.15	49.20
TNT[9]	85.70	80.40	83.80	92.00	79.10	91.20	85.37	-	-	-	-	-	-	-
UniOT	86.97	**88.48**	**88.35**	**98.83**	**87.60**	**96.57**	**91.13**	**59.30**	47.79	**51.79**	**46.81**	**48.32**	**58.25**	**52.04**

+6%!

+3%!

Comparison with state-of-the-arts

H^3-score(%) on **Office** and **Office-Home.**

	Office							Office-Home											
	A2D	A2W	D2A	D2W	W2A	W2D	Avg	Ar2Cl	Ar2Pr	Ar2Rw	Cl2Ar	Cl2Pr	Cl2Rw	Pr2Ar	Pr2Cl	Pr2Rw	Rw2Ar	Rw2Cl	Rw2Pr	Avg
ResNet[21]	53.90	51.79	46.81	59.15	46.54	61.32	53.25	41.42	50.88	49.56	43.55	46.98	46.62	45.65	40.38	50.08	46.57	41.70	50.84	46.18
UAN[40]	66.15	64.20	57.90	72.63	57.93	75.73	65.76	48.86	57.19	58.35	58.80	61.42	62.80	51.67	46.11	63.24	60.69	49.40	67.62	57.18
DANCE[33]	73.19	68.53	67.88	81.09	65.61	85.70	73.67	40.92	40.95	45.84	29.73	20.26	36.97	52.63	48.23	50.13	22.78	44.89	58.29	40.97
DCC[24]	**84.47**	74.80	63.54	87.09	69.58	71.55	75.17	55.64	78.21	78.18	44.64	33.77	69.96	63.77	53.81	65.10	63.17	53.58	**80.09**	61.66
UniOT	83.69	**85.28**	**71.46**	**91.24**	**70.93**	**90.84**	**82.24**	**60.11**	**78.72**	**79.53**	**65.83**	**75.32**	**76.83**	**68.21**	**56.83**	**80.55**	**69.62**	**58.74**	79.84	**70.84**

+7%!

+9%!

Ablation study

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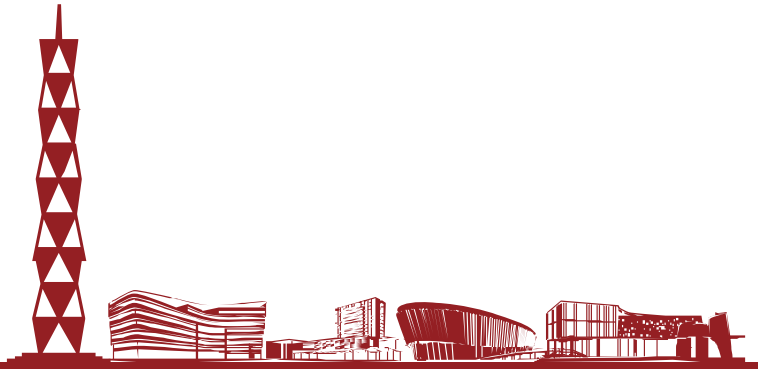
Common Class Discovery

Private Class Discovery

$\mathcal{L}_{CCD}$	$\mathcal{L}^{\dagger}_{CCD}$	$\mathcal{L}_{global}$	$\mathcal{L}_{local}$	H-score						H^3-score					
				Office			Office-Home			Office			Office-Home		
				A2W	D2A	Avg (6 tasks)	Ar2Pr	Cl2Rw	Avg (12 tasks)	A2W	D2A	Avg (6 tasks)	Ar2Pr	Cl2Rw	Avg (12 tasks)
✓				77.98	87.79	83.57	71.21	74.24	69.73	69.95	67.44	72.94	64.84	59.30	58.18
✓			✓	86.81	86.36	88.44	73.53	76.49	71.40	82.95	67.88	81.18	73.14	69.37	65.34
✓		✓		87.71	84.71	89.04	80.00	83.83	76.07	80.36	66.31	77.68	78.32	76.73	69.89
		✓	✓	74.18	72.61	79.74	79.59	74.24	75.55	75.38	62.08	76.18	78.42	76.12	70.44
	✓	✓	✓	87.84	**89.19**	89.86	75.10	79.14	72.65	81.25	70.75	80.49	75.28	74.02	68.31
✓		✓	✓	**88.48**	88.35	**91.13**	**80.54**	**84.28**	**76.57**	**85.28**	**71.46**	**82.24**	**78.72**	**76.83**	**70.84**

w/o adaptive filling

Table 4: Evaluation of the effectiveness of the proposed CCD and PCD.



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Robustness in realistic UniDA

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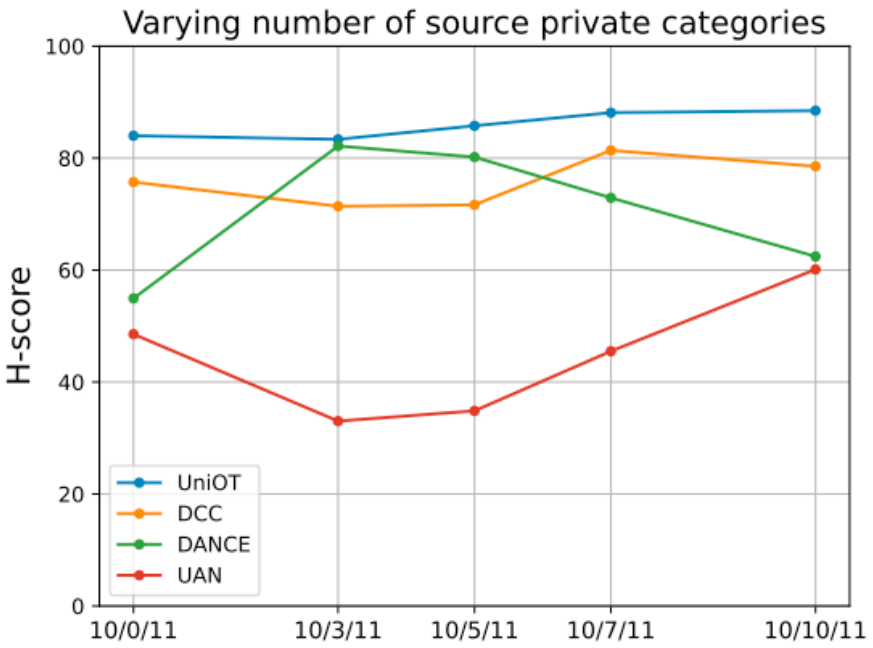
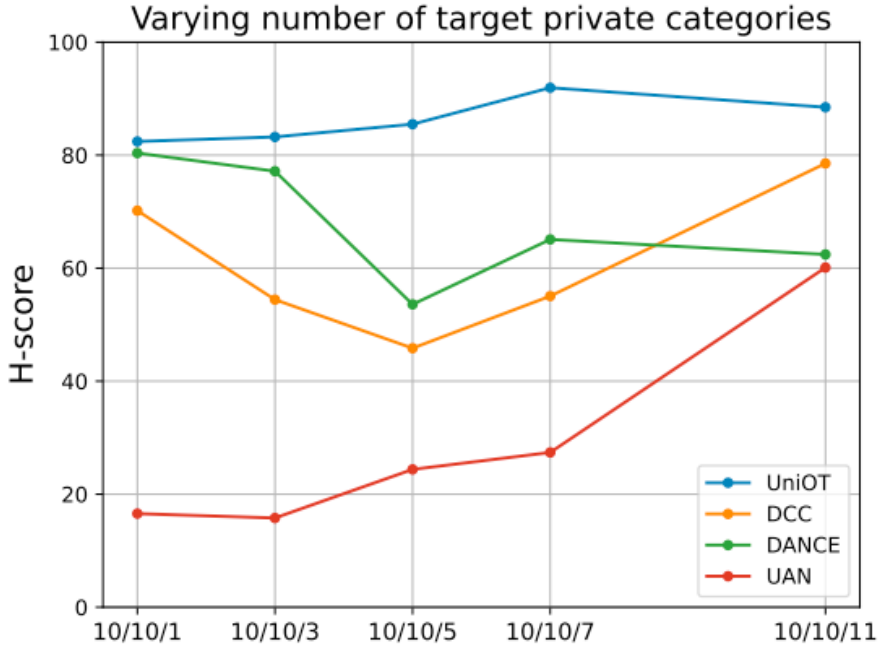


Ratio of common/source-private/target-private



Ratio of common/source-private/target-private

😀 ✓ more robust!

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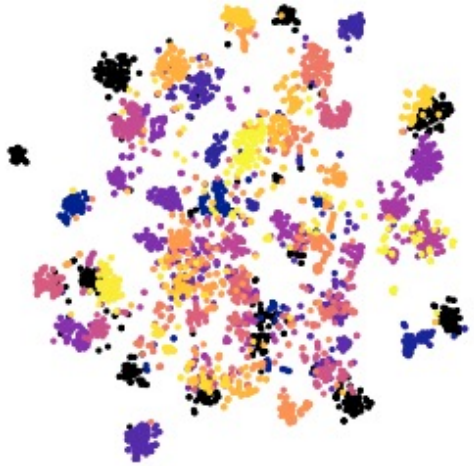
Feature visualization of target domain

(a) source-only



(b) UAN

(c) DANCE

(d) UniOT

- ✓ **global discrimination of clusters**
- ✓ **local consistency of samples**

Conclusion

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We have proposed to use Optimal Transport to handle common class detection and private class discovery for UniDA under a unified framework, namely UniOT.

- ✓ Unified OT framework
- ✓ robust for realistic UniDA, without tuning threshold parameter
- ✓ recognize different categories among target-private samples, learn better target representation

scan QR code for more details