Multi-batch Nuclear-norm Adversarial Network for Unsupervised Domain Adaptation

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Contributions

- **Feature Queue**: cache features to generate a large and consistent outputs

- **Probability Rescaling**: avoid the negative effect of overconfident and noisy predictions

- **Multi-batch Nuclear-norm Discrepancy**: enhance the transferability and discriminability of the learned features

Code@: *https://github.com/peiwang0518/Multi-BAN*

Conceptual comparison

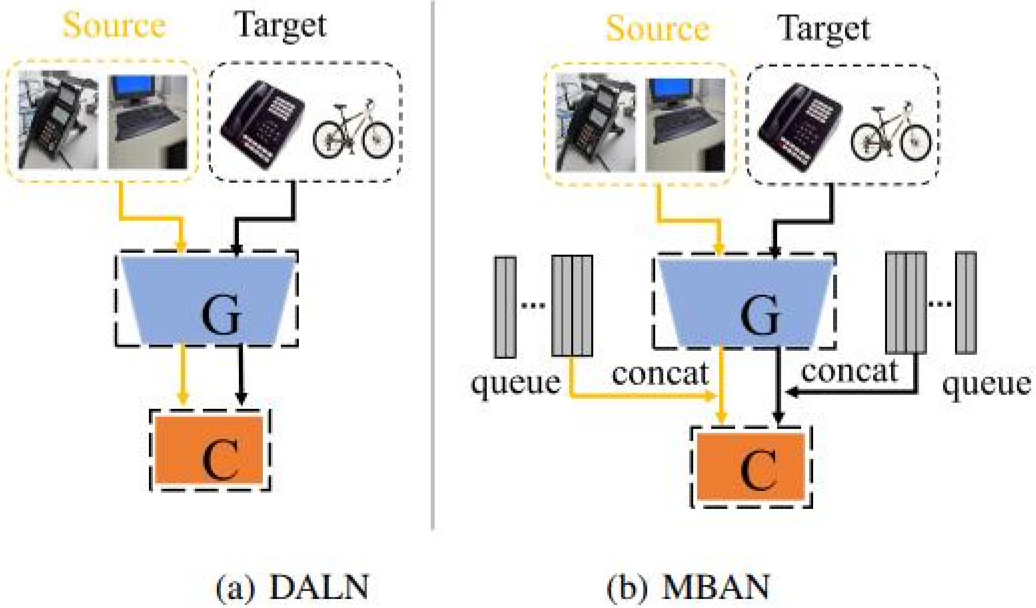


Fig. 1: Conceptual comparison of two adversarial learning paradigms.

Multi-batch Nuclear-norm Adversarial Network

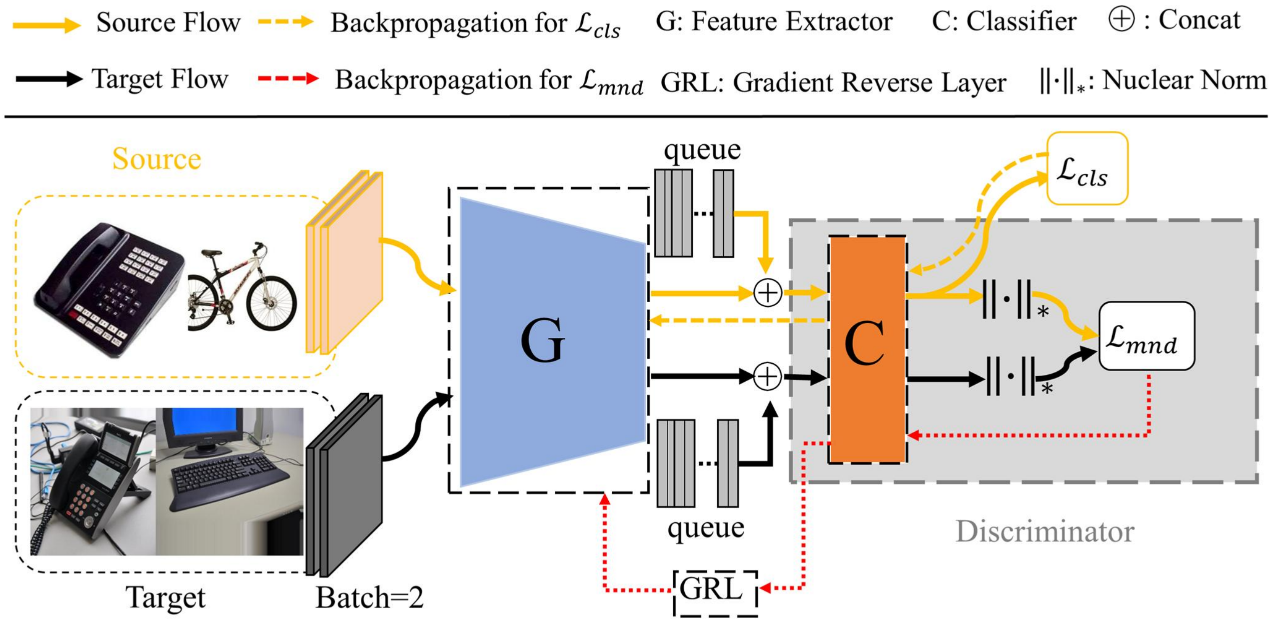


Fig. 2: The schematic of MBAN.

多批量核范数对抗领域自适应网络

（1） Feature queue

The current mini-batch is enqueued and the oldest mini-batch is removed from the queue

（2） Probability rescaling on target domain

$$\hat{Y}_{ij} = \frac{\exp\left(Z_{ij} / T\right)}{\sum_{j'=1}^{K} \exp\left(Z_{ij'} / T\right)},$$

T temperature parameter for probability rescaling

（3） Multi-batch nuclear-norm discrepancy (MND)

$$\mathcal{L}_{mnd} = \frac{1}{n_s^b}\left\|\widehat{\mathbf{Y}}_s\right\|_* - \frac{1}{n_t^b}\left\|\widehat{\mathbf{Y}}_t\right\|_*,$$

$$\widehat{\mathbf{Y}}_s = C\left(\left[G(\mathbf{X}_s) \oplus \mathbf{A}_s\right]\right)$$

$$\widehat{\mathbf{Y}}_t = C\left(\left[G(\mathbf{X}_t) \oplus \mathbf{A}_t\right]\right)$$

Overall function

$$\mathcal{L}_{mban} = \mathcal{L}_{cls} - \beta \mathcal{L}_{mnd},$$

Min supervised training loss on source domain

$$\mathcal{L}_{cls} = \frac{1}{n_s} \sum_{i=1}^{n_s} \mathcal{L}_{ce}\left(x_i^s, y_i^s\right)$$

min-max game

$$\min_G \max_C \mathcal{L}_{mnd}.$$

Theoretical insight

Expected error on target domain

$$蝌_t(h) \leq {}_s(h) + 2IW_1(P,Q) + {}_{ideal}(h^*),$$

where $\eta^* = \varepsilon_s(h^*) + \varepsilon_t(h^*)$ *is the error of ideal joint hypothesis* $h^* \in \mathcal{H}$ *on source and target domain, which is a sufficiently small constant.*

Results

TABLE I: Accuracy (%) on (a) Office-Home (ResNet-50) and (b) VisDA-2017 (ResNet-101) for UDA. † denotes that the results are cited from [12]. * denotes that the results are reproduced using the publicly released code.

(a) Office-Home.

Method	A→C	A→P	A→R	C→A	C→P	C→R	P→A	P→C	P→R	R→A	R→C	R→P	AVG
ResNet-50 [1]	34.9	50.0	58.0	37.4	41.9	46.2	38.5	31.2	60.4	53.9	41.2	59.9	46.1
DANN [8]	45.6	59.3	70.1	47.0	58.5	60.9	46.1	43.7	68.5	63.2	51.8	76.8	57.6
CDAN [3]	50.7	70.6	76.0	57.6	70.0	70.0	57.4	50.9	77.3	70.9	56.7	81.6	65.8
DSAN [7]	54.4	70.8	75.4	60.4	67.8	68.0	62.6	55.9	78.5	73.8	60.6	83.1	67.6
BNM [18]	52.3	73.9	80.0	63.3	72.9	74.9	61.7	49.5	79.7	70.5	53.6	82.2	67.9
MDD [22]	54.9	73.7	77.8	60.0	71.4	71.8	61.2	53.6	78.1	72.5	60.2	82.3	68.1
MCC [19]	55.1	75.2	79.5	63.3	73.2	75.8	66.1	52.1	76.9	73.8	58.4	83.6	69.4
GATE [23]	54.6	76.9	79.8	66.1	73.5	74.2	65.3	54.8	80.6	73.9	59.5	83.7	70.2
MetaAlign [5]	59.3	76.0	80.2	65.7	74.7	75.1	65.7	56.5	81.6	74.1	61.1	85.2	71.3
SCDA [25]	57.5	76.9	80.3	65.7	74.9	74.5	65.5	53.6	79.8	**74.5**	59.6	83.7	70.5
DALN [12]	57.8	**79.9**	82.0	66.3	76.2	77.2	66.7	55.5	81.3	73.5	60.4	85.3	71.8
InfoMLP [21]	59.6	77.3	79.5	67.4	75.9	74.6	66.1	56.4	81.0	**74.5**	61.4	84.4	71.5
MBAN(Ours)	**60.0**	79.4	**82.9**	**67.9**	**77.8**	**79.0**	**66.8**	**57.7**	**82.8**	74.3	**61.8**	**85.6**	**73.0**

(b) VisDA-2017.

Method	AVG
ResNet-101 [1]	52.4
DANN [8]	57.4
MCD [9]	71.9
CDAN [3]	73.9
BNM [18]	70.4
DSAN [7]	75.1
MDD*	77.3
MCC [19]	78.8
DADA [11]	79.8
GATE [23]	74.8
SCDA† [12]	79.7
DALN [12]	80.6
InfoMLP [21]	81.4
MBAN(Ours)	**82.7**

TABLE II: Accuracy (%) on Office-31 for UDA (ResNet-50).

Method	A→W	D→W	W→D	A→D	D→A	W→A	AVG
ResNet-50 [1]	68.4±0.5	96.7±0.5	99.3±0.1	68.9±0.2	62.5±0.3	60.7±0.3	76.1
DANN [8]	82.0±0.4	96.9±0.2	99.1±0.1	79.7±0.4	68.2±0.4	67.4±0.5	82.2
CDAN [3]	94.1±0.1	98.6±0.1	**100.0±0.0**	92.9±0.2	71.0±0.3	69.3±0.3	87.7
DSAN [7]	93.6±0.2	98.3±0.1	**100.0±0.0**	90.2±0.7	73.5±0.5	74.8±0.4	88.4
BNM [18]	91.5	98.5	**100.0**	90.3	70.9	71.6	87.1
MDD [22]	94.5±0.3	98.4±0.1	**100.0±0.0**	93.5±0.2	74.6±0.3	72.2±0.1	88.9
MCC [19]	**95.5±0.2**	98.6±0.1	**100.0±0.0**	94.4±0.3	72.9±0.2	74.9±0.3	89.4
DADA [11]	92.3±0.1	**99.2±0.1**	**100.0±0.0**	93.9±0.2	74.4±0.1	74.2±0.1	89.0
GATE [23]	90.5	98.7	**100.0**	91.3	73.4	75.9	88.3
MetaAlign [5]	93.0±0.5	98.6±0.0	**100.0±0.0**	94.5±0.3	75.0±0.3	73.6±0.0	89.2
SCDA [25]	94.2	98.7	99.8	<u>95.2</u>	75.7	76.2	90.0
DALN [12]	<u>95.2</u>	<u>99.1</u>	**100.0**	**95.4**	76.4	76.5	90.4
InfoMLP [21]	93.3±0.5	99.0±0.1	**100.0±0.0**	93.2±0.3	76.7±0.2	76.2±0.3	89.7
MBAN(w/ output)	95.0±0.7	98.6±0.3	99.8±0.2	95.0±0.3	**77.5±0.5**	<u>77.9±0.3</u>	<u>90.6</u>
MBAN(Ours)	**95.5±0.4**	98.6±0.3	<u>99.9±0.2</u>	95.1±0.3	<u>77.4±0.7</u>	**78.2±0.2**	**90.8**

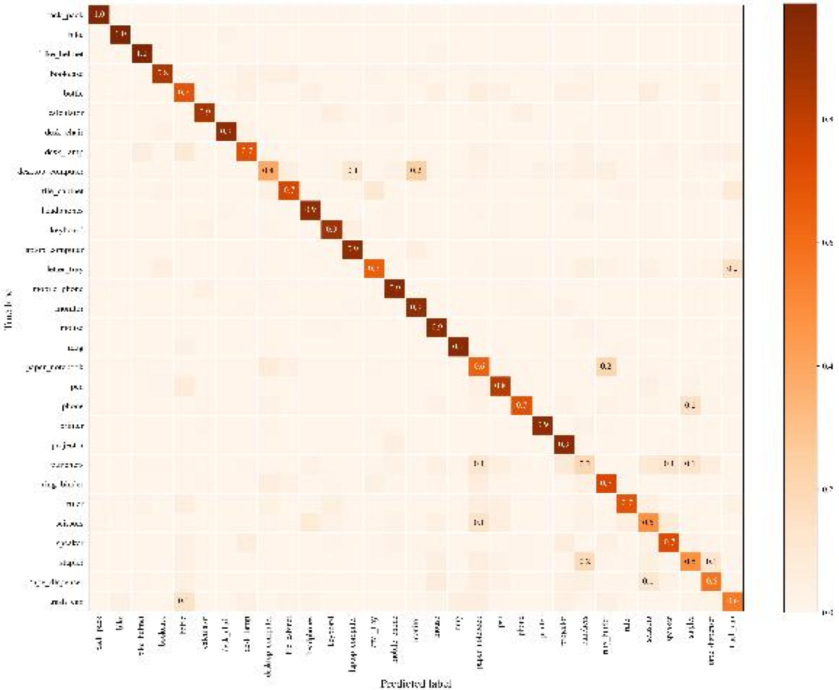
Analysis

Ablation study

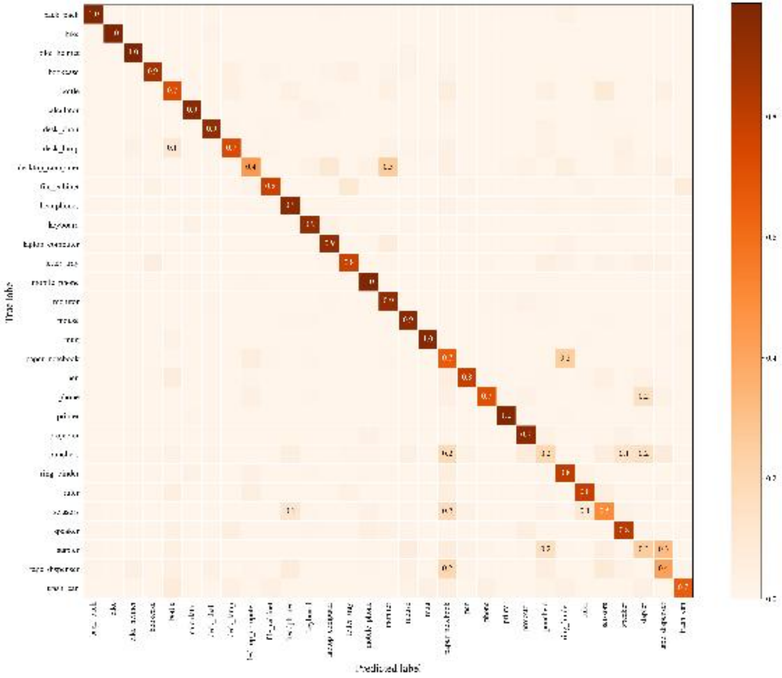
TABLE II: Accuracy (%) on Office-31 for UDA (ResNet-50).

Method	A→W	D→W	W→D	A→D	D→A	W→A	AVG
ResNet-50 [1]	68.4±0.5	96.7±0.5	99.3±0.1	68.9±0.2	62.5±0.3	60.7±0.3	76.1
DANN [8]	82.0±0.4	96.9±0.2	99.1±0.1	79.7±0.4	68.2±0.4	67.4±0.5	82.2
CDAN [3]	94.1±0.1	98.6±0.1	**100.0±0.0**	92.9±0.2	71.0±0.3	69.3±0.3	87.7
DSAN [7]	93.6±0.2	98.3±0.1	**100.0±0.0**	90.2±0.7	73.5±0.5	74.8±0.4	88.4
BNM [18]	91.5	98.5	**100.0**	90.3	70.9	71.6	87.1
MDD [22]	94.5±0.3	98.4±0.1	**100.0±0.0**	93.5±0.2	74.6±0.3	72.2±0.1	88.9
MCC [19]	**95.5±0.2**	98.6±0.1	**100.0±0.0**	94.4±0.3	72.9±0.2	74.9±0.3	89.4
DADA [11]	92.3±0.1	**99.2±0.1**	**100.0±0.0**	93.9±0.2	74.4±0.1	74.2±0.1	89.0
GATE [23]	90.5	98.7	**100.0**	91.3	73.4	75.9	88.3
MetaAlign [5]	93.0±0.5	98.6±0.0	**100.0±0.0**	94.5±0.3	75.0±0.3	73.6±0.0	89.2
SCDA [25]	94.2	98.7	99.8	95.2	75.7	76.2	90.0
DALN [12]	95.2	99.1	**100.0**	**95.4**	76.4	76.5	90.4
InfoMLP [21]	93.3±0.5	99.0±0.1	**100.0±0.0**	93.2±0.3	76.7±0.2	76.2±0.3	89.7
MBAN(w/ output)	95.0±0.7	98.6±0.3	99.8±0.2	95.0±0.3	**77.5±0.5**	77.9±0.3	90.6
MBAN(Ours)	**95.5±0.4**	98.6±0.3	99.9±0.2	95.1±0.3	77.4±0.7	**78.2±0.2**	**90.8**

Confusion Matrix

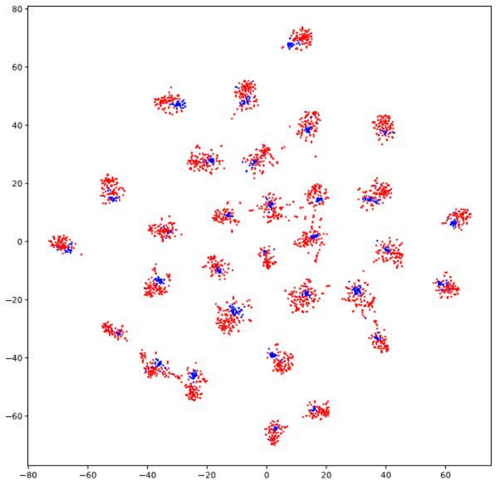


DALN

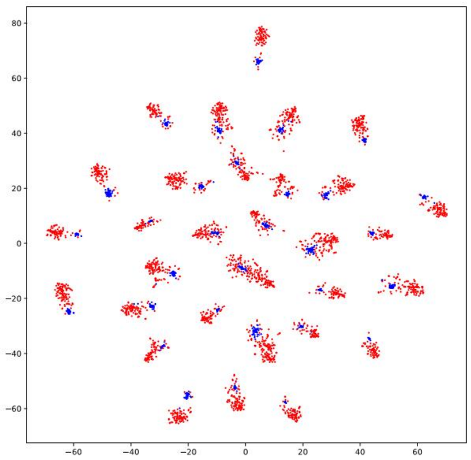


MBAN

Feature visualization

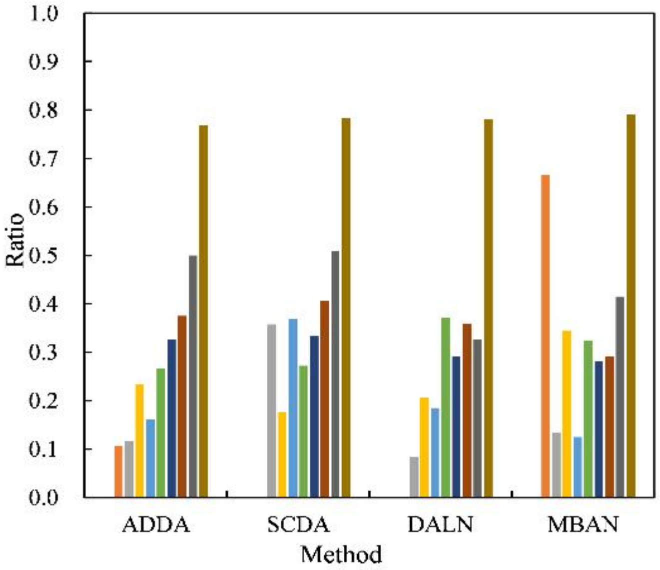


(b) DALN



(b) MBAN

Determinacy



Determinacy

Parameter Sensitivity

TABLE III: Accuracy (%) on Office-31 for sensitivity of queue length c. (ResNet-50).

queue length c	1	2	3	4
Avg	90.3	90.6	90.8	90.7

Thanks!

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Code

Email