Adaptive Domain Learning for Cross-Domain Image Denoising

Zian Qian[1], Chenyang Qi[1], Kalung Law[2], Hao Fu[2], Chenyang Lei[3], Qifeng Chen[1]

[1]The Hong Kong University of Science and Technology

[2]SenseTime

[3]CAIR, HKISI-CAS

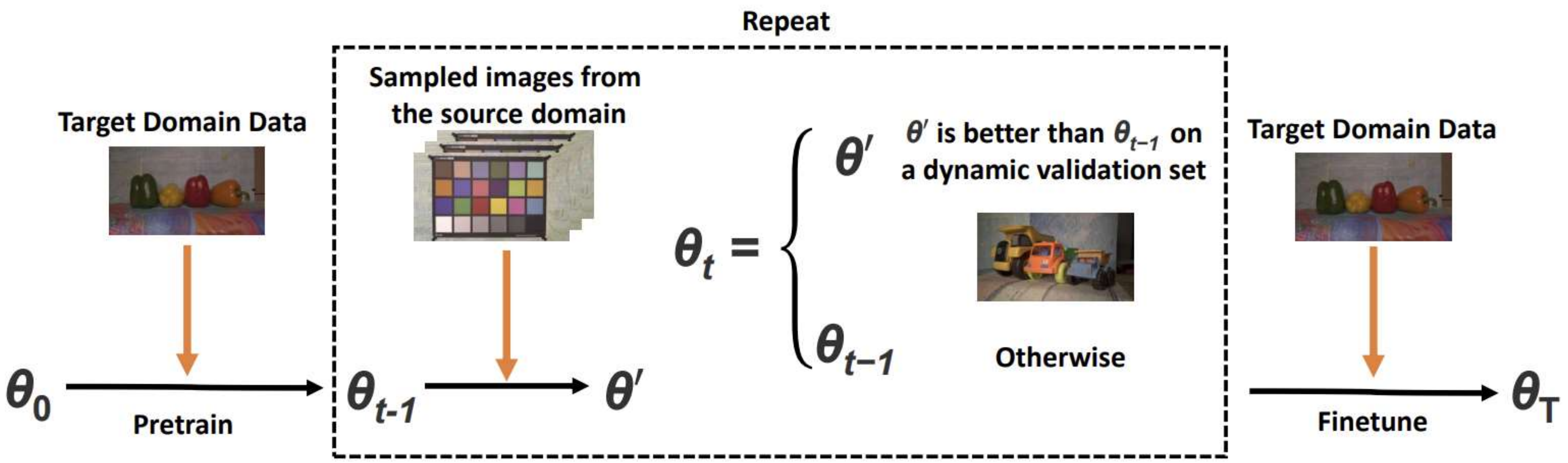
Motivation

- An RAW denoising model trained on one sensor often does not generalize well to a different sensor.
- Collecting a new large-scaled dataset for each new sensor is very time consuming.
- The dataset collect for the training of other sensors cannot be used for the training of new sensors.

Key Idea

- Only collect a small dataset of the new sensor (Target Domain) with around 20 pairs of RAWs.
- Utilize the existing dataset from old sensors (Source Domain) to help the training of the denoising model of the new sensor.
- Leverage useful information and remove the harmful data of the source domain during the training process.

ADL Pipeline: Overview



ADL Pipeline: Algorithm

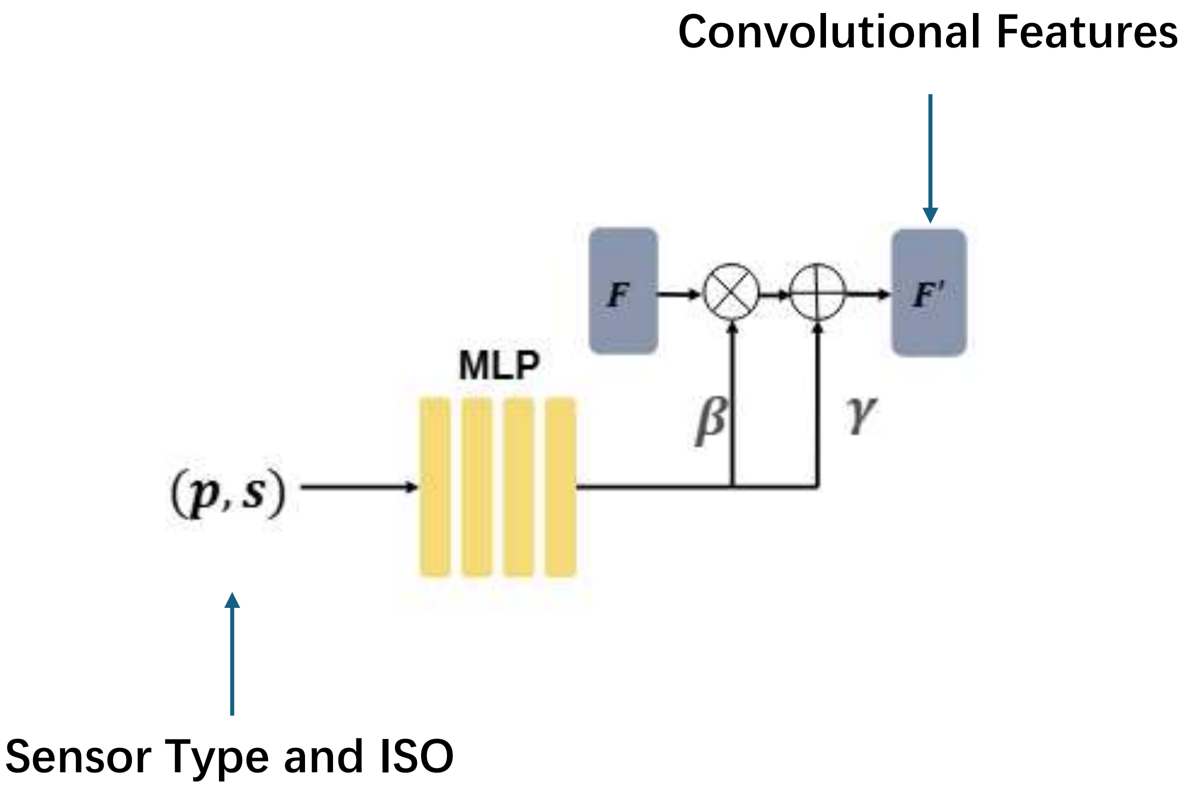
Algorithm 1 Adaptive domain learning (ADL)

Require: $S_1, \dots, S_n$: training sets of n source domains
Require: T^{adp}: The small target domain dataset

Require: Q^{eval}: priority queue with max length M that stores the PSNR.

Initialize a model of θ_0 by pretraining on T^{adp}
for $t \leftarrow 1$ to T **do**
  Randomly sample images S' from some domain S_i
  Randomly sample images V' from T^{adp}, the rest part $T^{train} = T^{adp} - V'$
  Merge S' and T^{train} by $S' = T^{train} + S'$
  $\theta' \leftarrow \theta_{t-1} - \alpha \nabla_{\theta_{t-1}} \mathcal{L}(S')$
  if $Eval(V', \theta') > \frac{1}{m} \sum_{i=1}^{m} Q_i^{eval}$ **then**
    $\theta_t = \theta'$
    if $Q.size() == M$ **then**
      $Q^{eval}.pop()$
    $Q^{eval}.push(Eval(V', \theta'))$
  else
    $\theta_t = \theta_{t-1}$
Fine-tune the model of θ_T on T^{adp}

ADL Pipeline: Modulation



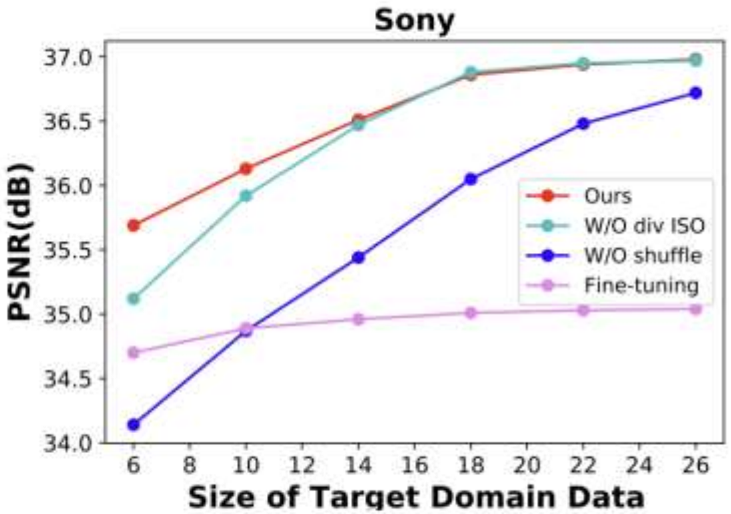
Result: Quantitative

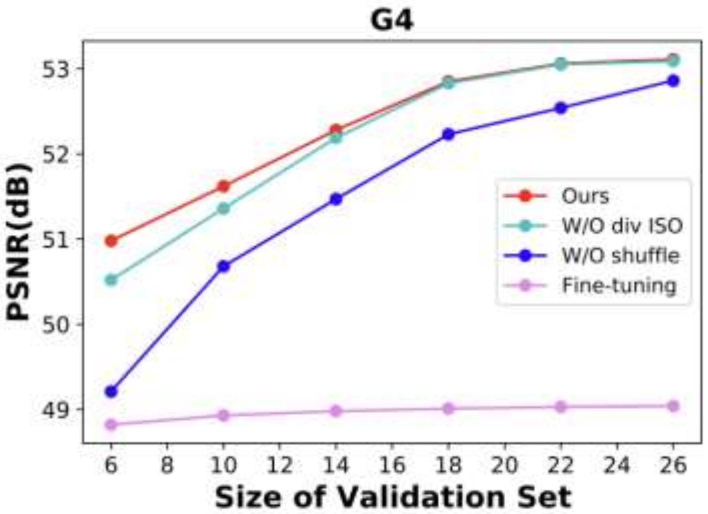
Method	G4	GP	IP	N6	S6	Avg.
Fine-tuning	50.17/0.968	43.53/0.914	52.77/0.977	43.86/0.917	37.88/0.863	45.58/0.928
BM3D [6]	50.08/0.968	42.14/0.909	52.39/0.972	43.40/0.916	35.52/0.855	44.71/0.924
DIP [31]	46.91/0.931	39.88/0.896	48.81/0.955	41.73/0.906	35.23/0.855	42.51/0.909
ZS-N2N [22]	48.86/0.941	41.54/0.909	50.06/0.968	41.88/0.910	35.07/0.856	43.48/0.917
MZSR [29]	51.84/0.972	44.58/0.921	53.74/0.982	45.07/0.924	37.21/0.868	46.49/0.933
Transfer learning [15]	52.28/0.974	44.96/0.923	53.04/0.982	44.77/0.923	40.10/0.898	47.03/0.940
Blind2Unblind [34]	51.78/0.970	44.91/0.919	54.12/0.985	46.02/0.928	38.85/0.892	47.14/0.939
Prabhakar et al. [28]	51.76/0.972	44.68/0.919	53.82/0.983	44.92/0.922	38.67/0.878	46.34/0.933
Ours	**52.55/0.975**	**45.18/0.923**	**54.37/0.987**	**46.13/0.932**	**40.16/0.901**	**47.68/0.944**

Method	Sony	Fuji	Nikon	Canon	Avg.
Fine-tuning	35.94/0.857	36.37/0.862	35.22/0.853	35.63/0.855	35.79/0.857
BM3D [6]	35.61/0.856	35.88/0.857	35.37/0.853	35.07/0.852	35.48/0.855
DIP [31]	31.02/0.696	29.44/0.611	30.71/0.652	30.53/0.641	30.42/0.650
ZS-N2N [22]	32.15/0.724	30.39/0.632	30.46/0.643	31.34/0.707	31.09/0.677
MZSR [29]	36.21/0.861	36.98/0.866	36.14/0.860	35.89/0.857	36.31/0.861
Transfer learning [15]	36.92/0.864	37.33/0.869	36.49/0.862	35.77/0.858	36.63/0.863
Blind2Unblind [34]	36.71/0.866	36.57/0.866	35.88/0.857	35.49/0.855	36.16/0.861
Prabhakar et al. [28]	36.12/0.859	36.33/0.864	35.47/0.854	35.72/0.857	36.01/0.861
Ours	**37.28/0.871**	**37.58/0.872**	**36.74/0.866**	**36.45/0.868**	**37.01/0.868**

Result: Ablation Study

ADL	ISO	Type	Pre	Dyn	Sony	Fuji	Nikon	Canon
✓	✓	✓		✓	36.15/0.858	36.44/0.859	36.52/0.861	36.00/ 0.857
✓		✓	✓	✓	37.13/0.868	37.41/0.871	36.66/0.860	36.27/0.857
✓	✓		✓	✓	36.81/0.862	36.93/0.864	36.46/0.858	36.11/0.855
	✓	✓	✓		35.88/0.855	36.14/0.856	35.97/0.856	34.69/0.788
✓	✓	✓	✓		36.89/0.866	37.41/0.871	36.42/0.862	36.23/0.861
✓	✓	✓	✓	✓	**37.28/0.871**	**37.58/0.872**	**36.74/0.866**	**36.45/0.864**





Result: Analysis

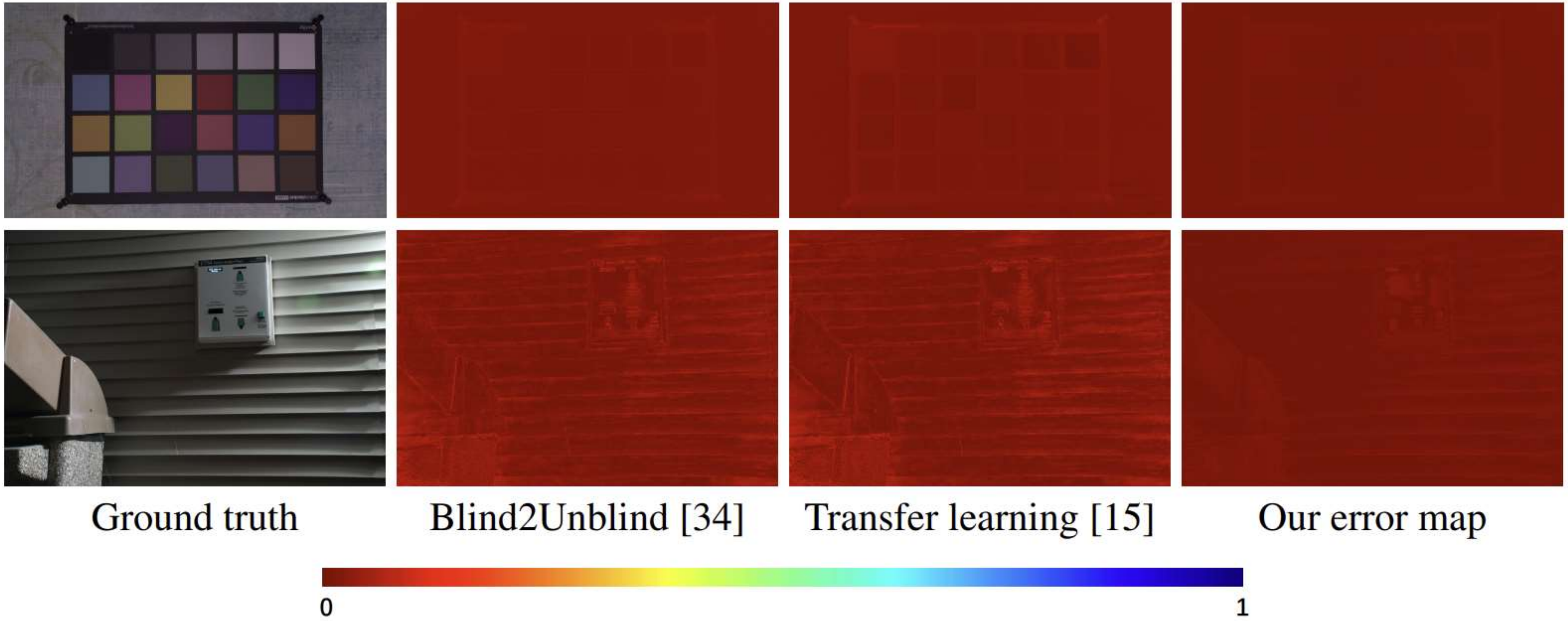
Dataset	Sensor	Zhang et al.	Single		Multiple	
			FT	ADL	FT	ADL
SIDD	GP	45.36	45.47	**45.62**	45.32	**45.83**
	S6	43.17	**43.45**	43.44	42.66	**43.69**
	IP	54.93	55.24	**55.37**	55.11	**55.68**
ELD	Sony	44.86	44.93	**44.98**	44.68	**45.17**
	Nikon	43.21	43.26	**43.34**	42.96	**43.54**

Analysis on Calibration methods

Sensor	Base	Base+Harmful1		Base+Harmful2	
	FT	FT	ADL	FT	ADL
Sony	35.01/0.805	34.59/0.772	35.13/0.812	19.06/0.216	34.99/0.808
Fuji	34.97/0.806	34.69/0.771	35.21/0.823	20.14/0.244	35.06/0.807
Nikon	34.68/0.782	34.42/0.765	35.85/0.853	21.26/0.297	34.62/0.782
Canon	34.76/0.794	34.37/0.752	34.88/0.797	21.17/0.268	34.71/0.792

Analysis on Harmful Data

Result: Qualitative



Thank you!