Iterative Filter Adaptive Network for Single Image Defocus Deblurring

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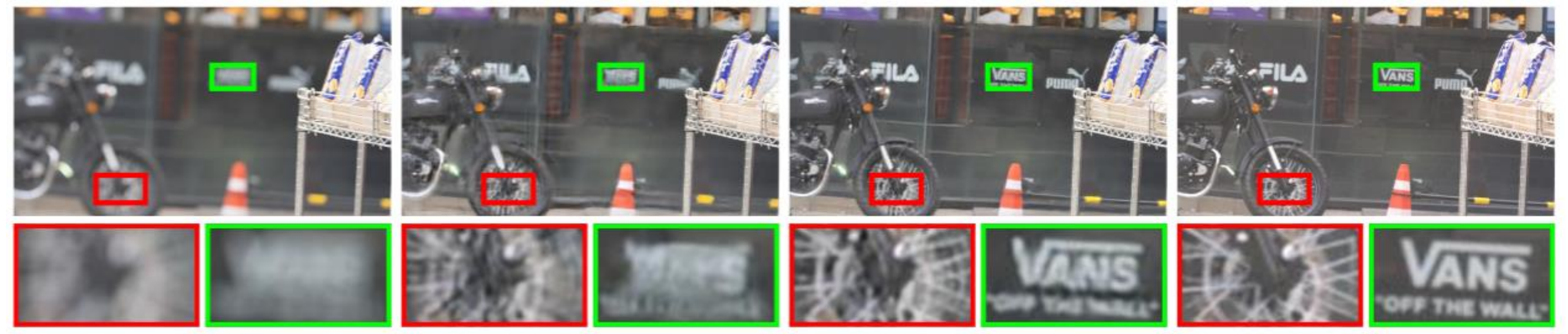
Defocus Deblurring

Restoration of an all-in-focus image from a defocused image



Input DPDNet [1] Ours GT

Qualitative comparison on the proposed RealDOF test set

Motivation

Challenging to deal with ***spatially varying and large blur***

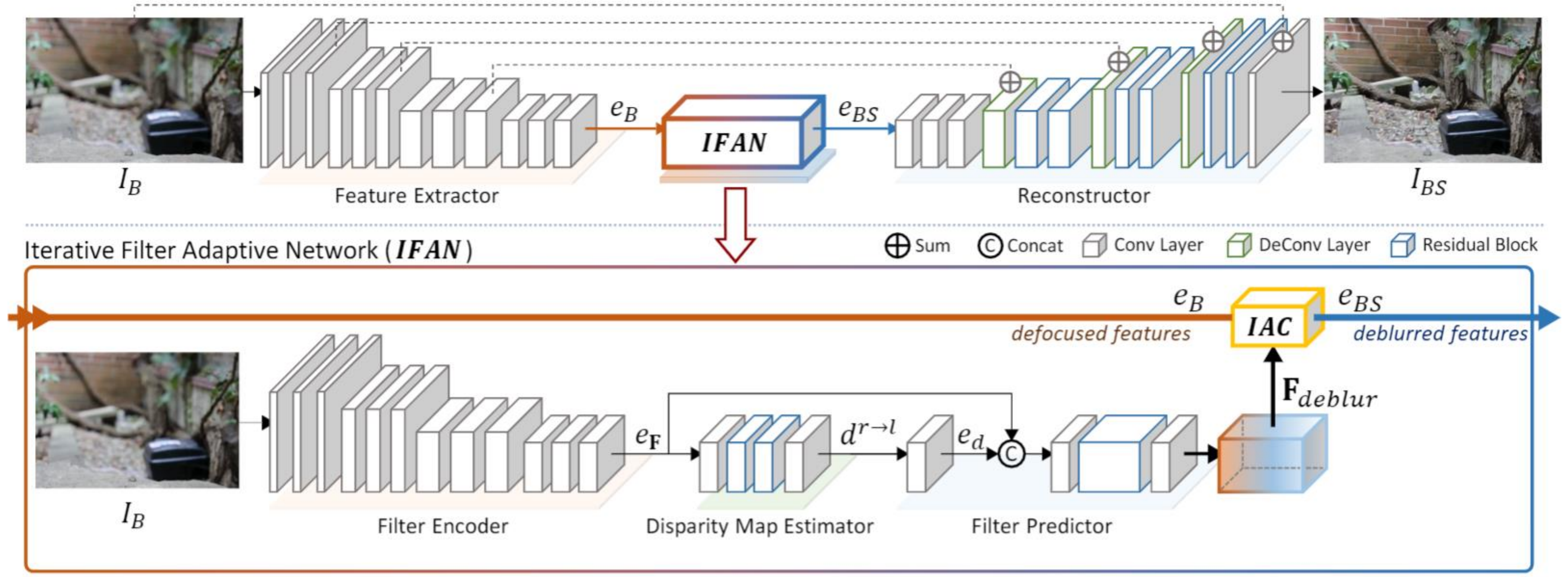
- **Conventional defocus map-based approaches [12, 14]**
  → Fails due to **restrictive blur model** (*e.g.* Gaussian) that constrains the blur shape
- **Recent end-to-end deep learning-based approach [1]**
  → Produces artifacts and remaining blur due to **naïve U-Net [26] architecture** that is not flexible for handling spatially varying and large defocus blur
  → Requires **dual-pixel images that are not easily obtainable** for ordinary camera users

So, we designed an end-to-end network that effectively handles ***spatially varying and large blur*** for ***a single image*** defocus deblurring

Contributions

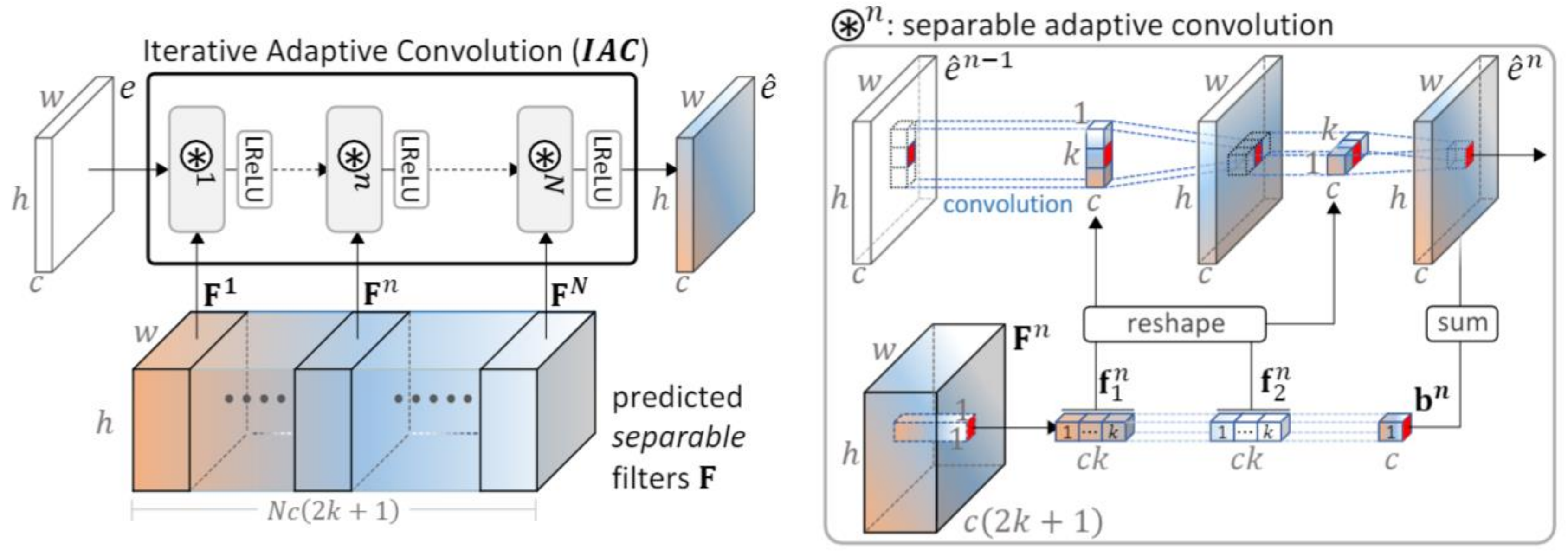
- **Iterative Filter Adaptive Network (*IFAN*)**
  → For effectively handle spatially varying and large blur
- **Disparity map estimation & reblurring**
  → Maximum use of defocus blur cues in a single image
- **The *RealDOF* test set for quantitative evaluation**
- **State-of-the-art performance of defocus deblurring**

Proposed Deblurring Network with Iterative Filter Adaptive Network (*IFAN*)



- Predicts **per-pixel stacked separable** filters $\mathbf{F}$, which is applied to defocused features by *IAC*
  → Per-pixel filters allows flexible handling of spatially varying blur

Iterative Adaptive Convolution (*IAC*) Layer



- Leveraging separable filters
  → Motivated by [34] that showed **1-dim filters** can approximate **a large inverse filter** for the deconvolution task
- Iterative applying of the separable filters
  → **Compensates possible error** may be caused by utilizing separable filters
  → Establishes **a large receptive field** for dealing with **large blur**

Training

- Trained with DPDD dataset [1]
- Objective functions
  - → Deblurring

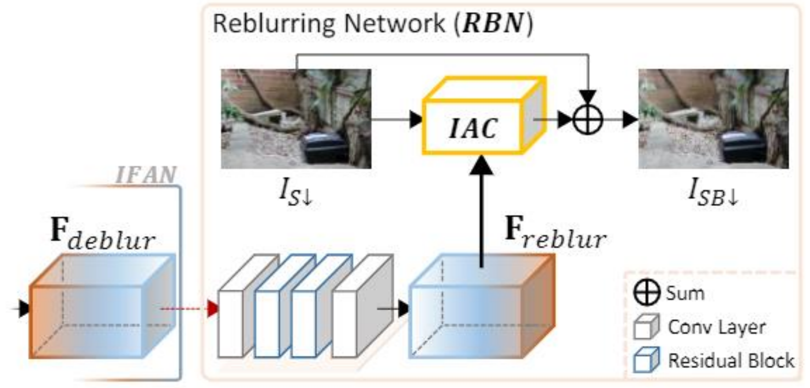
$$L_{deblur} = MSE(I_{BS}, I_S)$$

  - → Disparity Map Estimation

$$L_{disp} = MSE(I_{B\downarrow}^{r \to l}, I_{B\downarrow}^{l})$$

  - → Reblurring

$$L_{reblur} = MSE(I_{SB\downarrow}, I_{B\downarrow})$$



Real Depth of Field (*RealDOF*) Test Set

- Pair images are concurrently captured with the dual-camera system

Our image acquisition system for the RealDOF test set

Experimental Results

1) Ablation Study

$\mathcal{F}$: filter predictor + IAC layer D: disparity map estimator R: reblurring network

IFAN		$\mathcal{R}$	Evaluations on the DPDD Dataset [1]				Computational Costs	
$\mathcal{F}$	$\mathcal{D}$		PSNR↑	SSIM↑	MAE$_{(\times 10^{-1})}$↓	LPIPS↓	Params (M)	MACs (B)
			24.88	0.753	0.416	0.289	10.58	364.3
	✓		24.97	0.761	0.412	0.280		
✓			25.07	0.765	0.406	0.271	10.48	362.9
✓	✓		25.18	0.780	0.403	0.233		
✓		✓	25.28	0.780	0.400	0.245		
✓	✓	✓	**25.37**	**0.789**	**0.394**	**0.217**		

Quantitative results of an ablation study on the DPDD dataset [1]

2) Comparisons

Model	Evaluations the DPDD Dataset [1]				Computational Costs		
	PSNR↑	SSIM↑	MAE$_{(\times 10^{-1})}$↓	LPIPS↓	Params (M)	MACs (B)	Time (Sec)
Input	23.89	0.725	0.471	0.349	-	-	-
JNB [28]	23.69	0.707	0.480	0.442	-	-	105.8
EBDB [12]	23.94	0.723	0.468	0.402	-	-	96.58
DMENet [14]	23.90	0.720	0.470	0.410	26.94	1172.5	77.70
DPDNet$_S$ [1]	24.03	0.735	0.461	0.279	35.25	989.8	0.462
DPDNet$_D$ [1]	25.23	0.787	0.401	0.224	35.25	991.4	0.474
Ours	**25.37**	**0.789**	**0.394**	**0.217**	**10.48**	**362.9**	**0.014**

Quantitative comparison on the DPDD dataset [1]

Input DPDNet$_S$ Ours

Qualitative comparison on the CUHK dataset [27]

Model	PSNR↑	SSIM↑	MAE$_{(\times 10^{-1})}$↓	LPIPS↓
Input	22.33	0.633	0.513	0.524
JNB [28]	22.36	0.635	0.511	0.601
EBDB [12]	22.38	0.638	0.509	0.594
DMENet [14]	22.41	0.639	0.508	0.597
DPDNet$_S$ [1]	22.67	0.666	0.506	0.420
Ours	**24.71**	**0.748**	**0.407**	**0.306**

Quantitative comparison on the proposed RealDOF test set