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Filter-cluster attention based recursive network for low-light enhancement

Key words: Low-light enhancement; Filter-cluster attention; Dense connection pyramid; Recursive network

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Motivation

1. In some adverse environments, especially low-light scenes with uneven lighting, the light information received by the camera equipment is insufficient, and the collected images often show low brightness, poor clarity, and weak contrast. Therefore, it is of vast significance to construct a practical low-light enhancement framework to improve the quality of low-light images.

2. Deep learning methods have led to impressive improvements in low-light image visibility, but still fall short when there are excessive color changes in low-light scenes, and the color information loss problem is often seen in the deep network architecture.

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Main idea

1. Filter-cluster attention (FCA) is proposed to measure feature space and channel saliency, making the network pay more attention to defect regions and important channels.

2. Dense connection pyramid (DenCP) is added to extract inverted image features with high brightness, so the dark regions in each iterative learning can be enhanced.

3. A multi-stage recursive network is designed with the input consisting of low-light images and FCA results. After learning three units, i.e., difference concern, gate recurrent, and iterative residual, the learning results are further combined with DenCP to obtain the final output.

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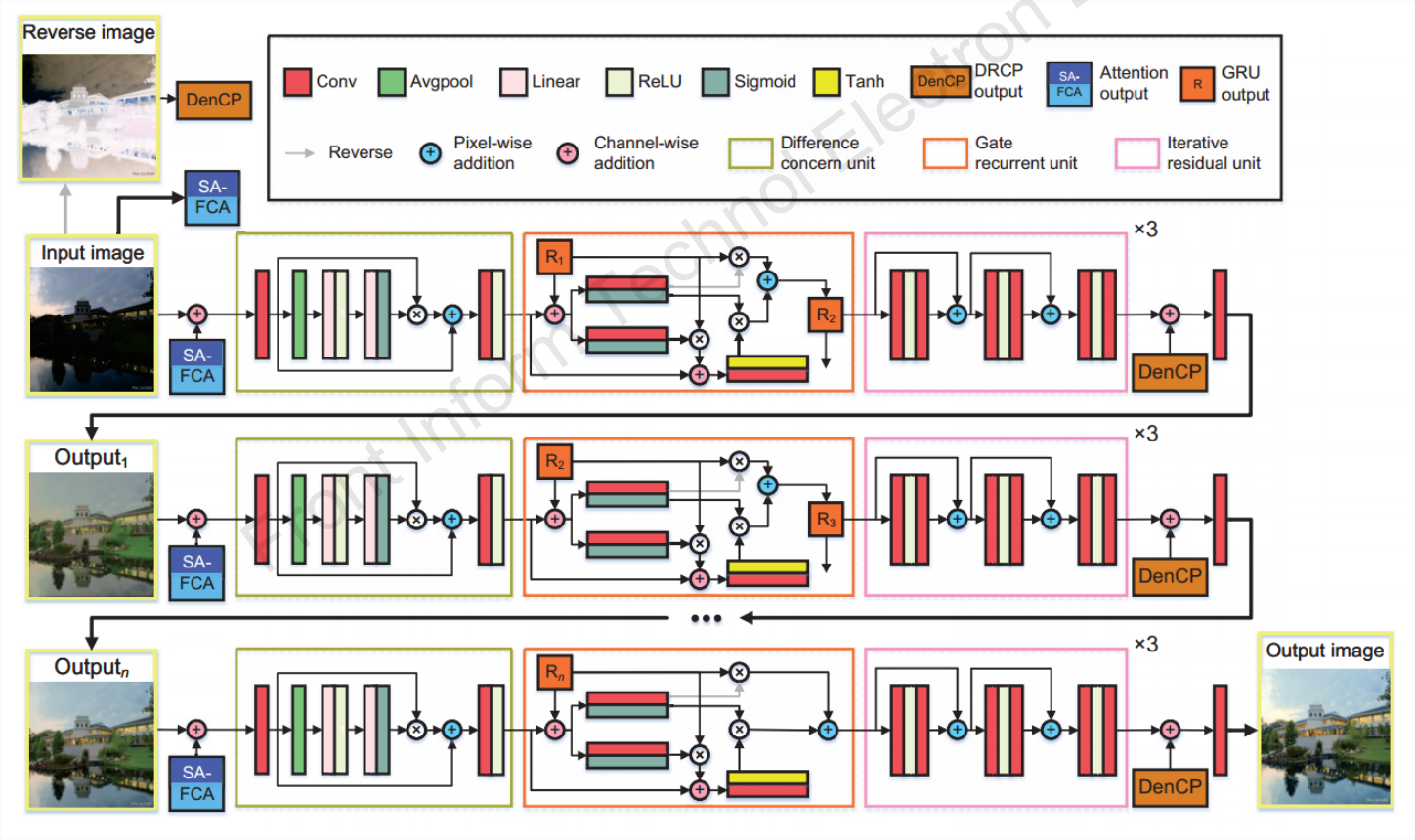
Methodology

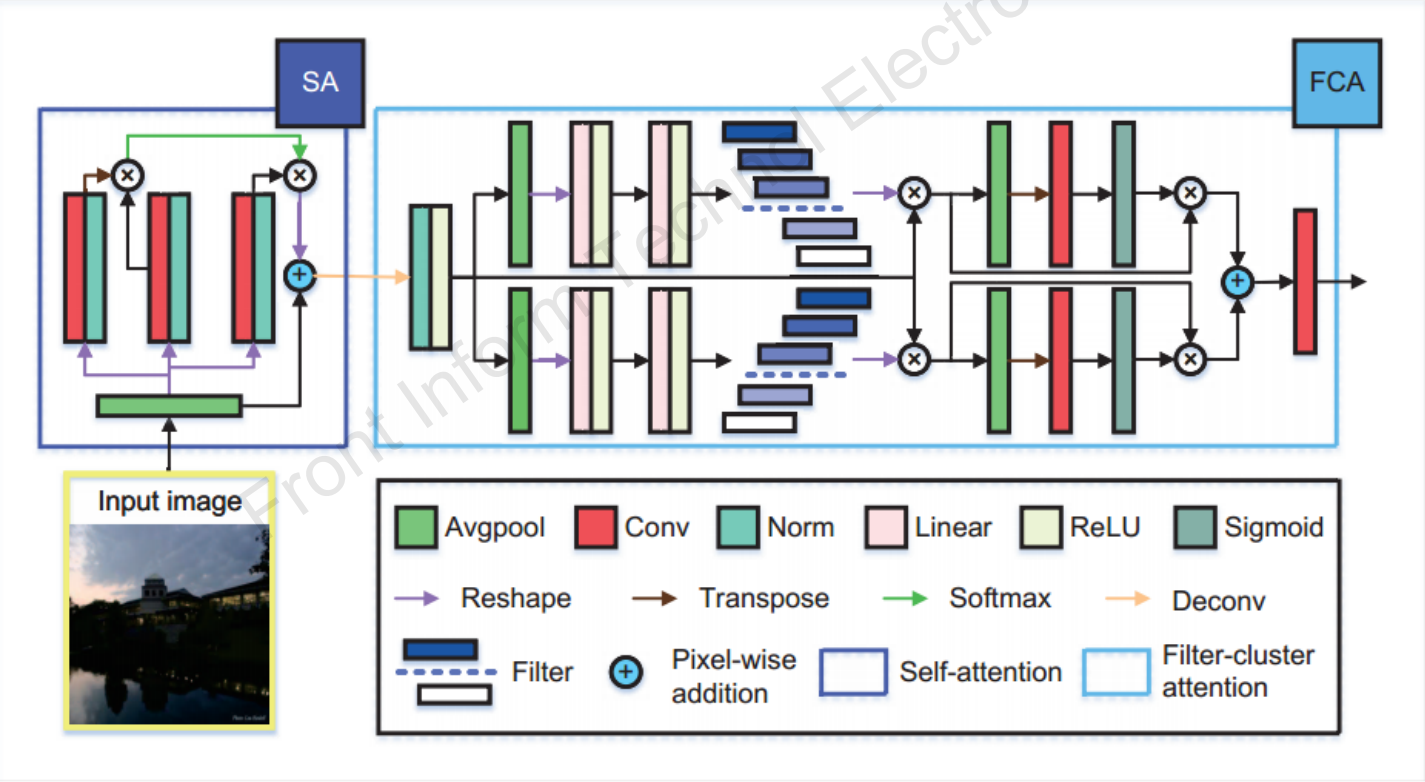
1. The network transforms low-light images into enhanced images after multiple iterations, with each iteration divided into three units: difference concern, gate recurrent, and iterative residual.



Architecture of the proposed network

Methodology

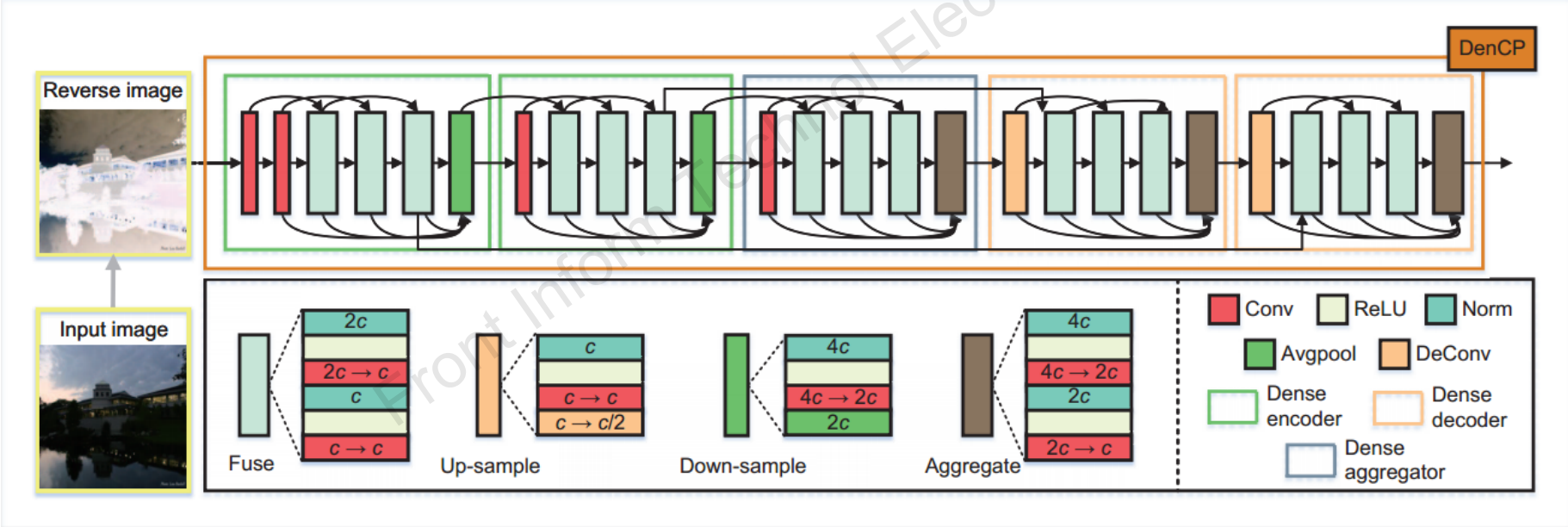
2. In this network, the input image first undergoes two stages of attention: self-attention (SA), which focuses on region correlation, and filter-cluster attention (FCA), which focuses on channel saliency and dependency.



Two-stage attention involved in the network

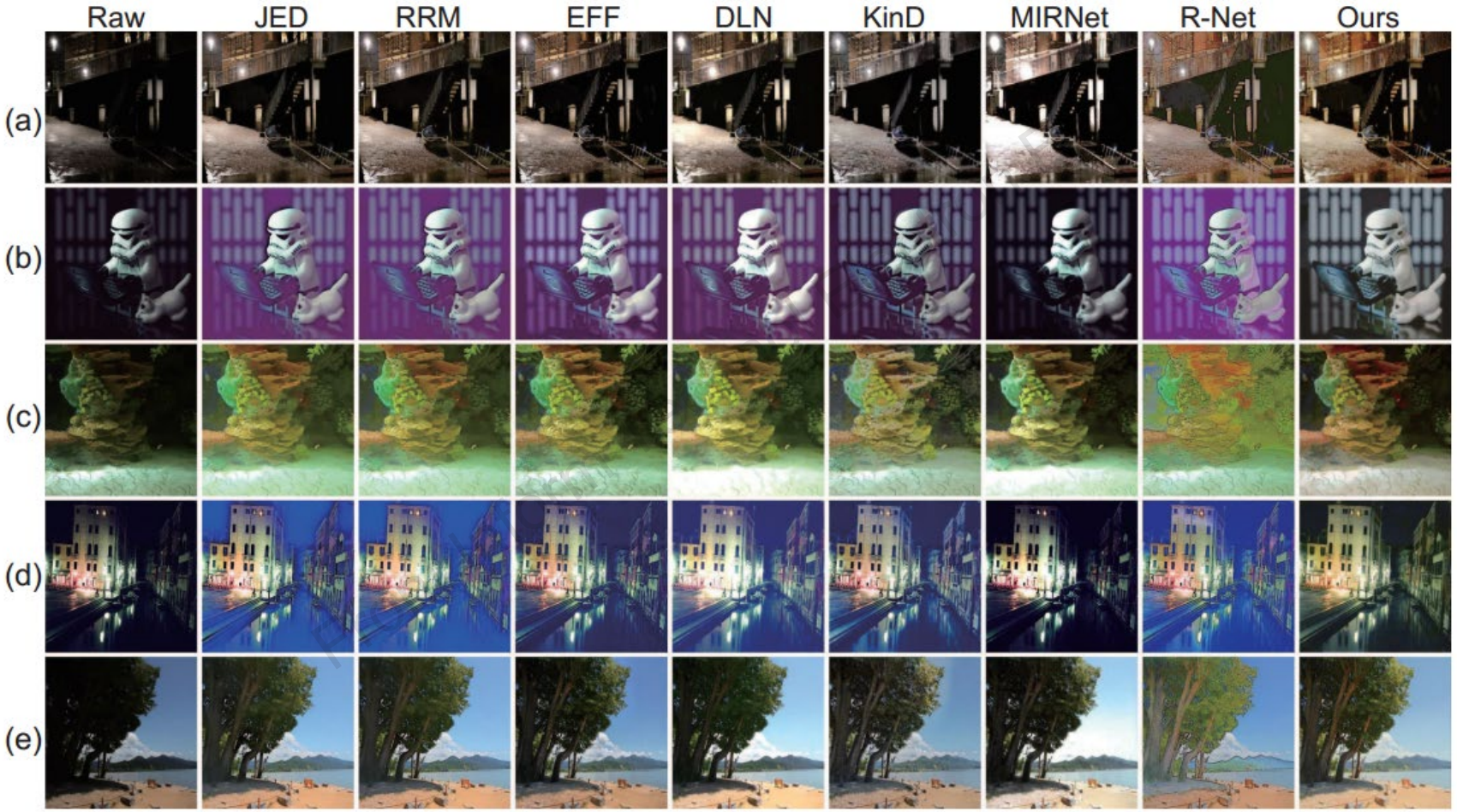
Methodology

3. Dense connection pyramid (DenCP) is proposed to exploit the similarity and difference of multi-scale features. After each iteration, DenCP uses the inversion images to extract the auxiliary brightness information.



Specific structure of DenCP

Experimental results



Comparison on no-reference datasets DICM, ExDark, and LIME, with (a) and (d) from the ExDark dataset, (b) from the LIME dataset, and (c) and (e) from the DICM dataset

Experimental results

The mean values of BRISQUE and ENTROPY on the NPE, DICM, ExDark, and LIME datasets

Method	BRISQUE				ENTROPY			
	NPE	DICM	ExDark	LIME	NPE	DICM	ExDark	LIME
JED	29.908	21.710	29.923	28.883	6.9446	6.8285	7.0567	6.0133
RRM	27.177	28.044	26.948	30.114	7.1836	7.0032	7.1836	<u>6.5648</u>
EFF	16.210	20.034	20.801	18.250	<u>7.1629</u>	6.7907	7.1038	6.0380
DLN	<u>18.988</u>	<u>16.205</u>	<u>17.010</u>	**15.199**	6.5529	6.8133	7.0411	6.1022
KinD	21.364	23.816	22.809	23.988	7.1237	**7.1751**	7.2066	6.1590
MIRNet	19.988	16.945	20.628	21.956	6.7444	6.9382	6.8717	5.9754
R-Net	25.742	32.819	23.955	27.837	7.0555	<u>7.0288</u>	<u>7.3379</u>	6.2415
Ours	**18.680**	**13.854**	**15.543**	<u>17.485</u>	**7.3419**	6.9630	**7.3710**	**6.5861**

The optimal values are in bold and the suboptimal values are underlined

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Conclusions

1. In this paper, we propose a recurrent network based on FCA, which consists of three units: difference concern, gate recurrent, and iterative residual. In addition, we design DenCP to extract features from the inverse image of low-light images.

2. Through extensive experiments on public datasets, the proposed method shows good brightness and visibility enhancement. In the future, we will apply FCA in the improved network structure to enrich the saturation and visual expression of the image.

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