

RCAN

Image Super-Resolution Using Very Deep Residual Channel
Attention Networks

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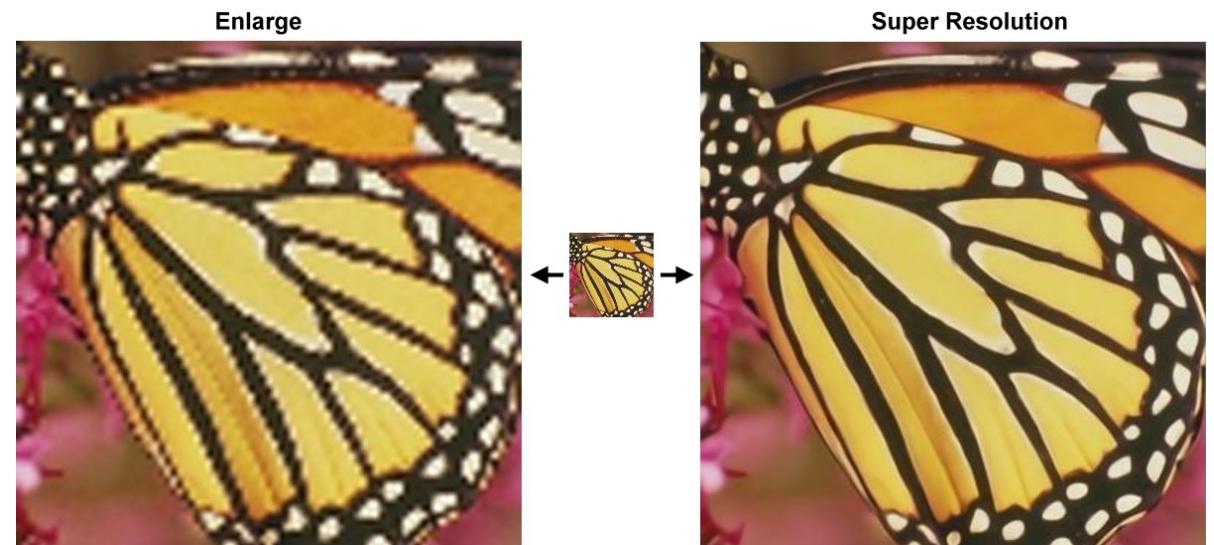
- **Concept of Super Resolution**
- **Prior studies**
- **What is RCAN**
- **Architecture**
 - **Residual in Residual**
 - **Channel Attention**
 - **Residual Channel Attention Blocks**

Concept of Super Resolution

LR to HR

Concept of Super Resolution

- LR to HR
- Methodology
 - Local prior
 - interpolation
 - cnn-based
 - Non-local prior
 - patch
 - cnn-based

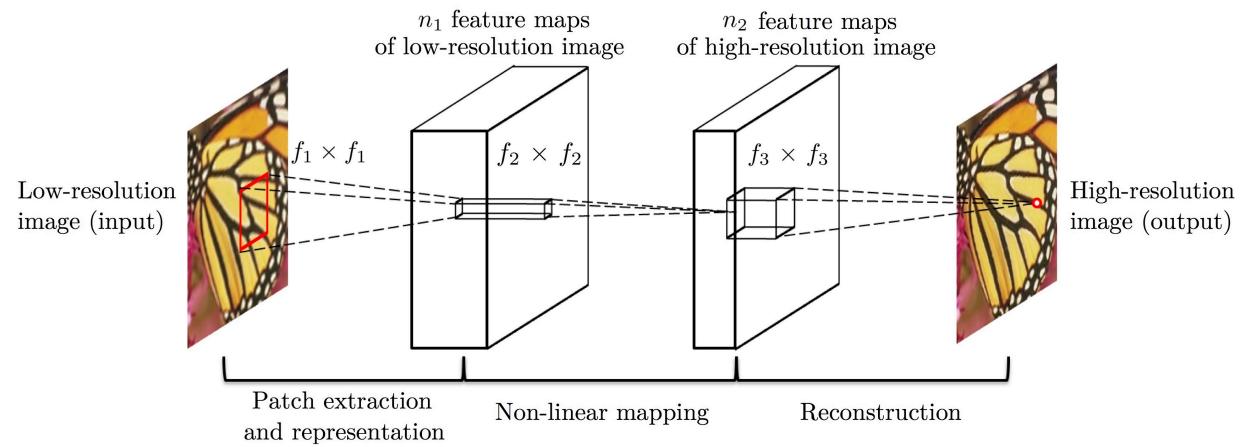


Prior studies

SRCNN, VDSR, SRGAN, EDSR, MDSR

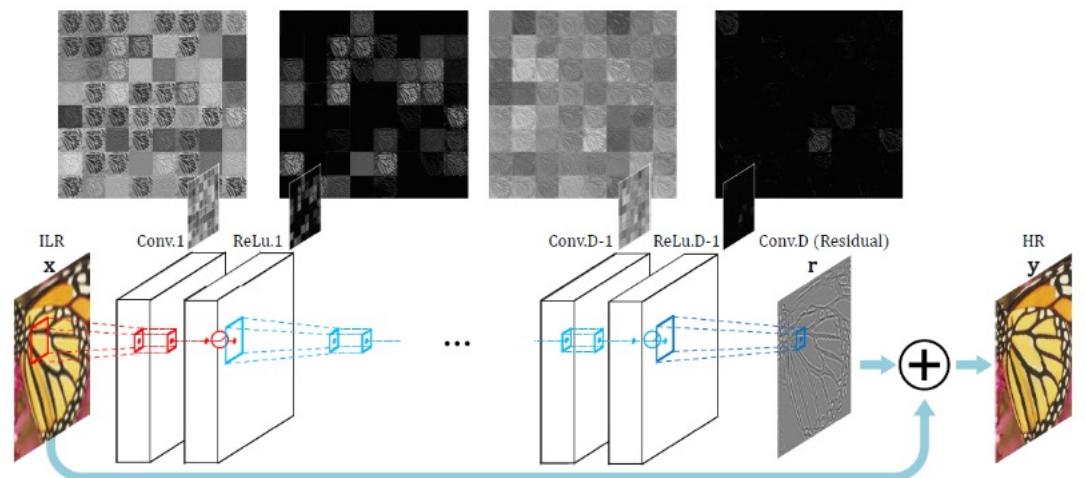
SRCNN

- Upscale
- LR feature map
- Non-linear mapping from F_{lr} to F_{hr}
- HR feature map
- Reconstruction
- MSE



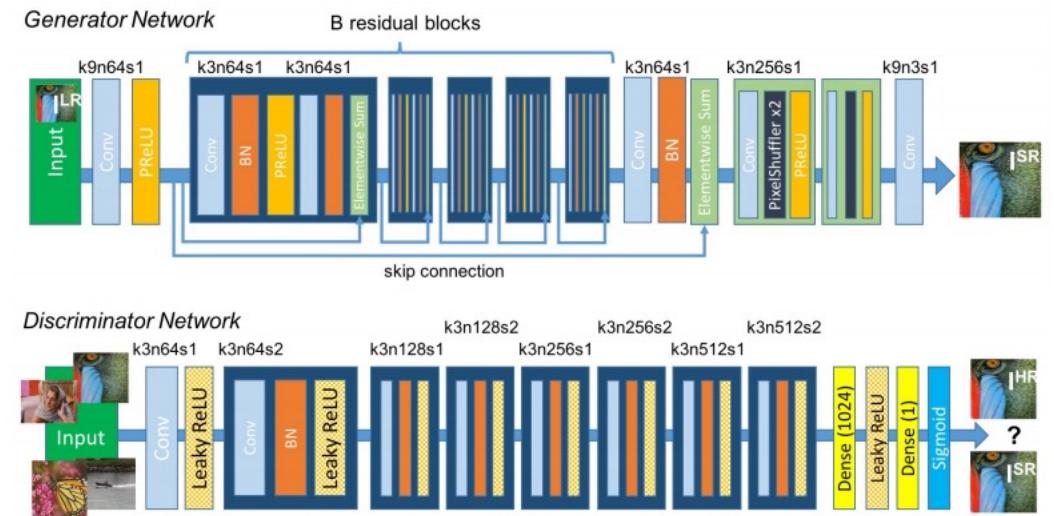
VDSR

- Deep. Inspired by VGG-net
- More contextual info
- “Residual” connection
- MSE



SRGAN

- GAN methodology
- Perceptual loss
- Less blur



EDSR, MDSR

- Advanced residual block
 - Remove BN layer
 - Less normalize, more detail
- L1 loss

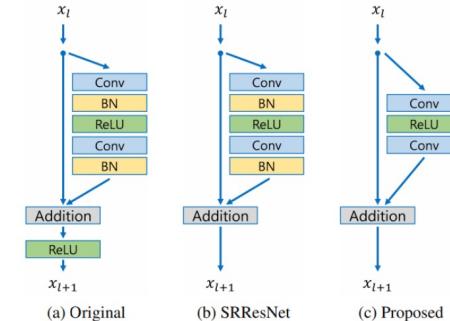


Fig4. comparison of residual blocks

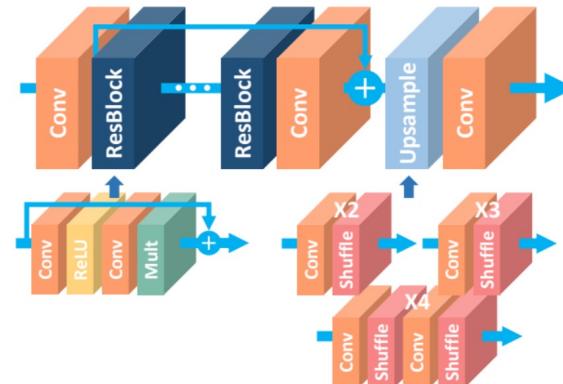


Fig5. EDSR(single-scale)architecture

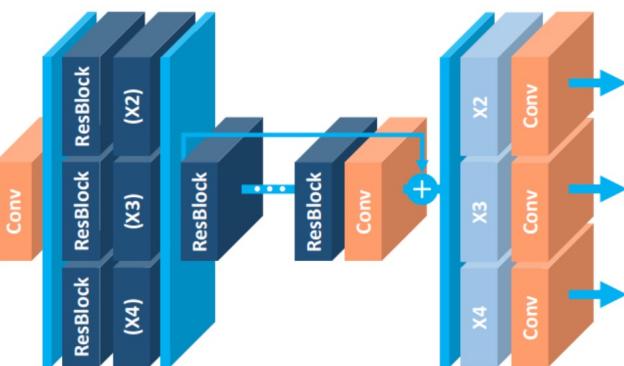


Fig6. MDSR(multi-scale) architecture

What is RCAN

Key points

What is RCAN

- SR model
- Channel Attention
- Rescale feature via intra-channel information
- L1 loss

Architecture

RIR, CA, RCAB

Architecture

Yulun Zhang *et al.*

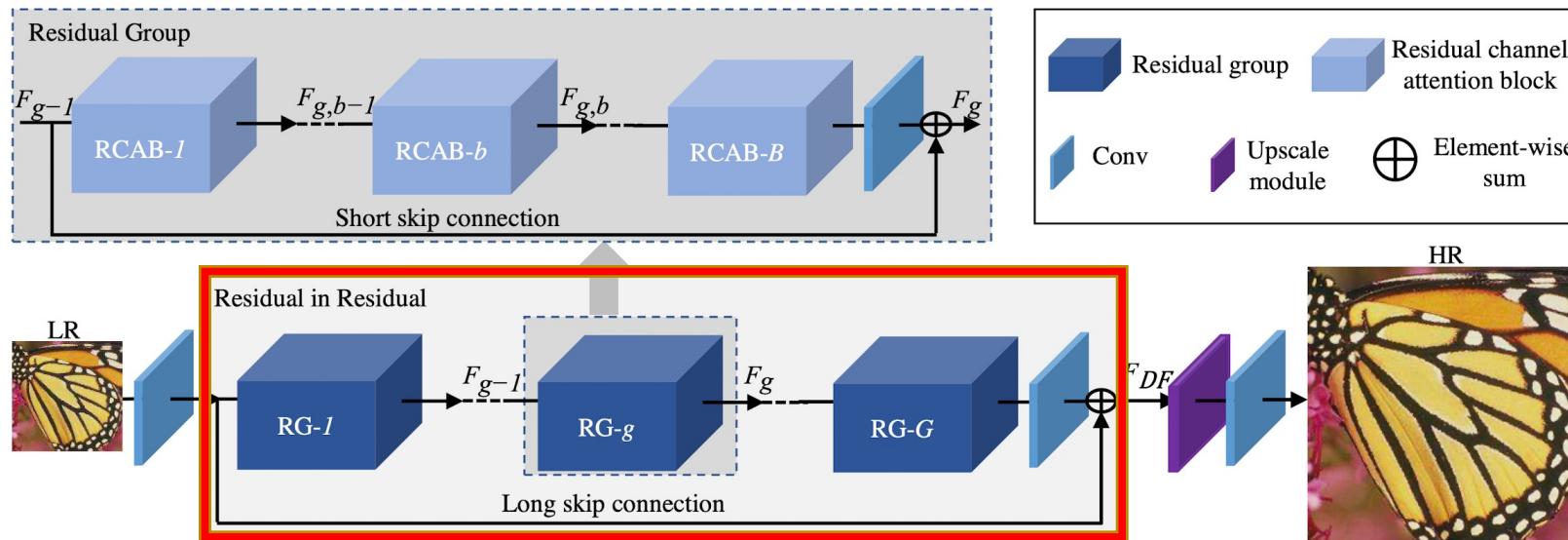


Fig. 2. Network architecture of our residual channel attention network (RCAN)

Architecture

- Shallow feature extraction
- RIR deep feature extraction
- Upscale module
- Reconstruction

Yulun Zhang *et al.*

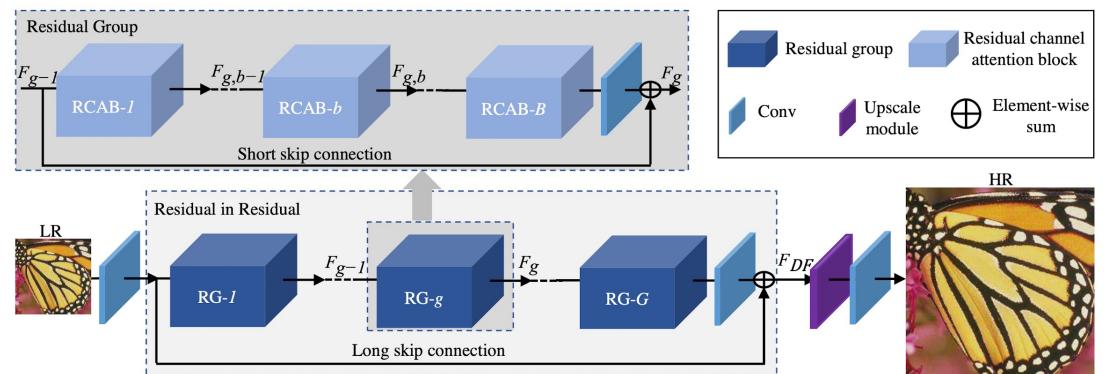


Fig. 2. Network architecture of our residual channel attention network (RCAN)

Architecture

- Residual in Residual
- Residual Group
- Residual Channel Attention Block

Yulun Zhang *et al.*

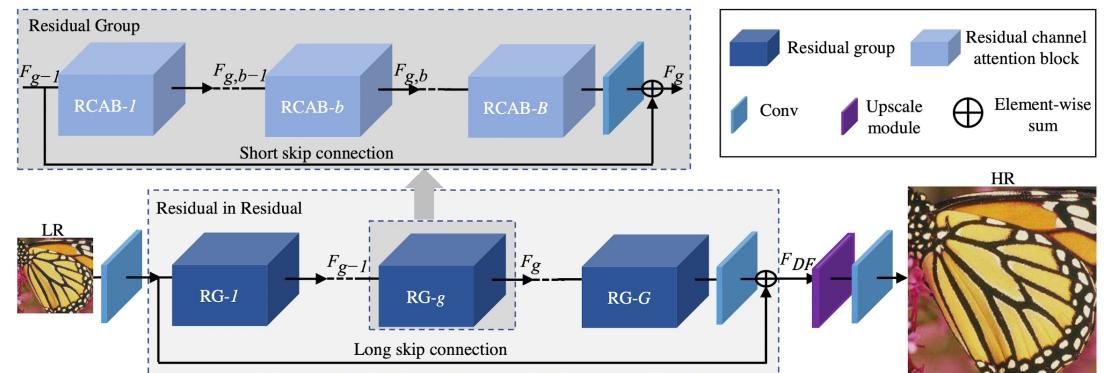


Fig. 2. Network architecture of our residual channel attention network (RCAN)

Residual in Residual

Yulun Zhang *et al.*

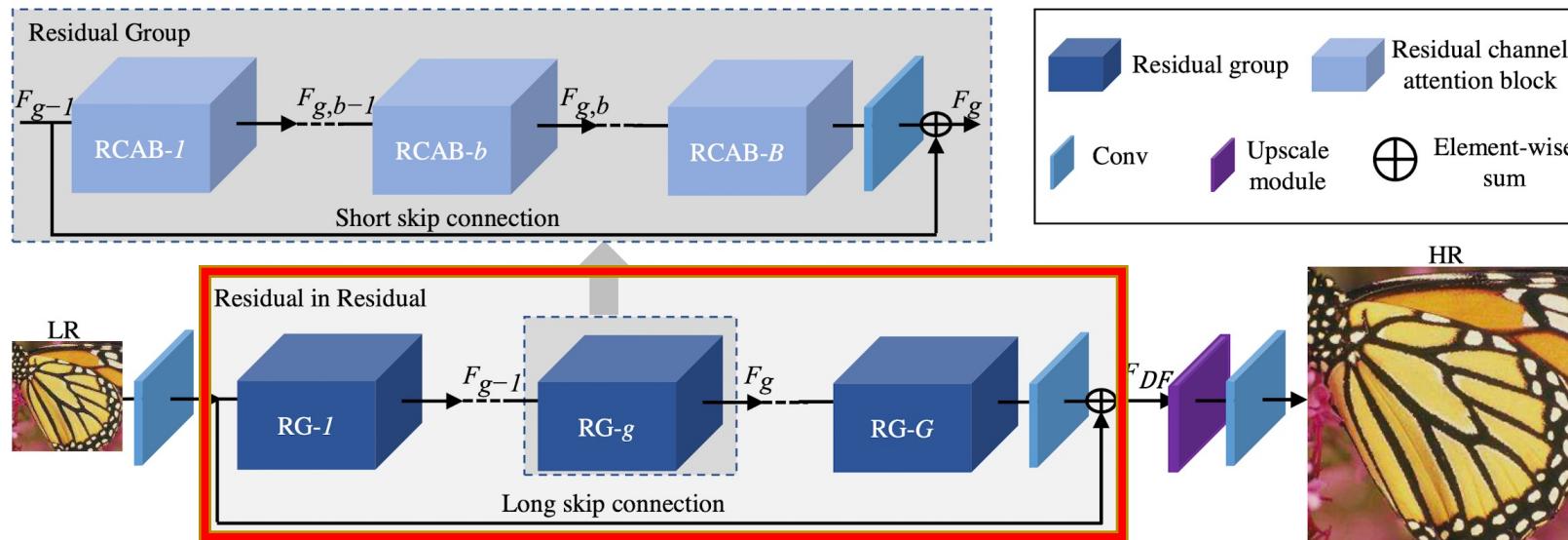


Fig. 2. Network architecture of our residual channel attention network (RCAN)

Residual Group

Yulun Zhang *et al.*

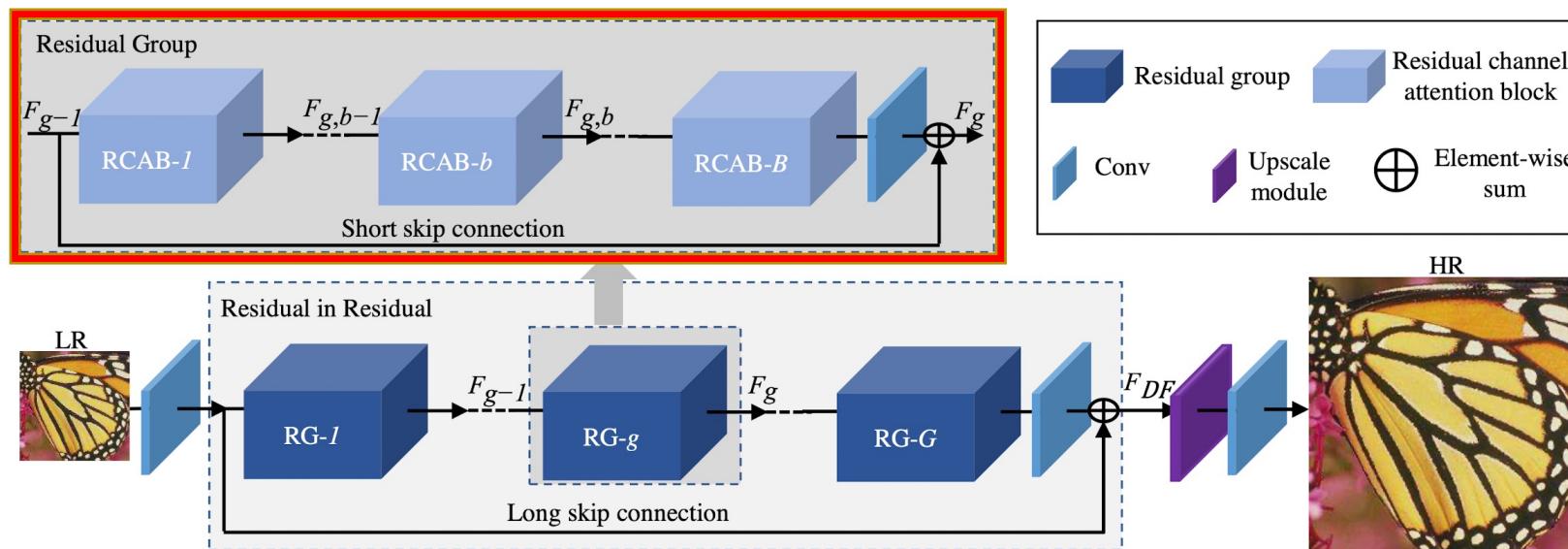


Fig. 2. Network architecture of our residual channel attention network (RCAN)

Residual Channel Attention Block

Yulun Zhang *et al.*

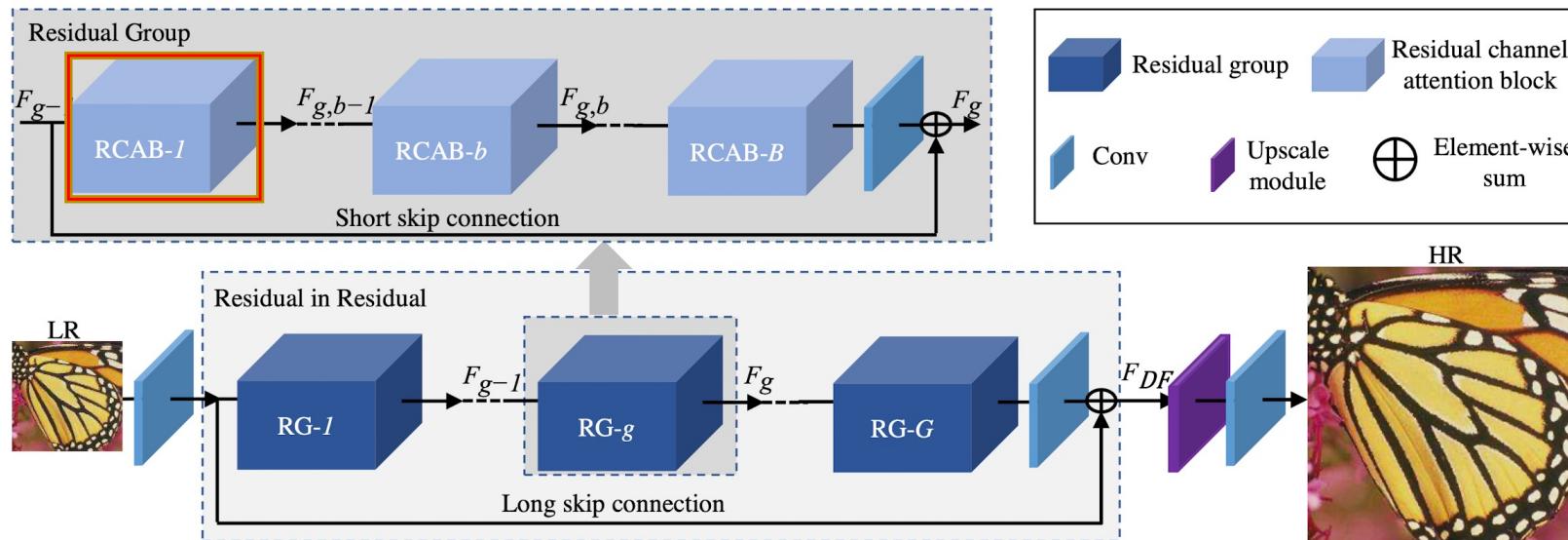


Fig. 2. Network architecture of our residual channel attention network (RCAN)

Residual Channel Attention Block

- High frequency : texture, edge
- Low frequency : complanate
- Global pooling
 - Contextual Information outside of the local region

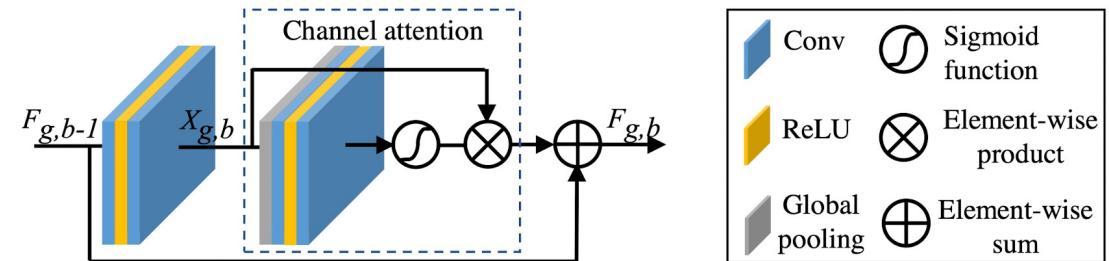


Fig. 4. Residual channel attention block (RCAB)

Table 1. Investigations of RIR (including LSC and SSC) and CA. We observe the best PSNR (dB) values on Set5 (2×) in 5×10^4 iterations

Residual in Residual (RIR)	LSC	✗	✓	✗	✓	✗	✓	✗	✓
	SSC	✗	✗	✓	✓	✗	✗	✓	✓
Channel attention (CA)		✗	✗	✗	✗	✓	✓	✓	✓
PSNR on Set5 (2×)		37.45	37.77	37.81	37.87	37.52	37.85	37.86	37.90

Channel Attention

- Global pooling
- Downscaling
- Upscaling

Yulun Zhang *et al.*

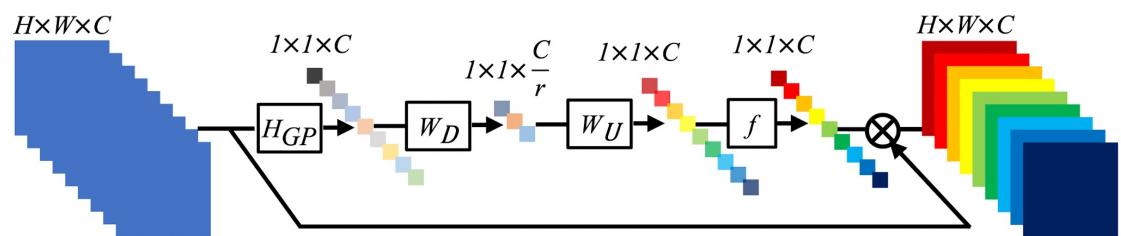


Fig. 3. Channel attention (CA). \otimes denotes element-wise product

Experiments

Experiments

Table 2. Quantitative results with BI degradation model. Best and second best results are **highlighted** and underlined

Method	Scale	Set5		Set14		B100		Urban100		Manga109	
		PSNR	SSIM								
Bicubic	$\times 2$	33.66	0.9299	30.24	0.8688	29.56	0.8431	26.88	0.8403	30.80	0.9339
SRCCNN [5]	$\times 2$	36.66	0.9542	32.45	0.9067	31.36	0.8879	29.50	0.8946	35.60	0.9663
FSRCCNN [6]	$\times 2$	37.05	0.9560	32.66	0.9090	31.53	0.8920	29.88	0.9020	36.67	0.9710
VDSR [16]	$\times 2$	37.53	0.9590	33.05	0.9130	31.90	0.8960	30.77	0.9140	37.22	0.9750
LapSRN [19]	$\times 2$	37.52	0.9591	33.08	0.9130	31.08	0.8950	30.41	0.9101	37.27	0.9740
MemNet [35]	$\times 2$	37.78	0.9597	33.28	0.9142	32.08	0.8978	31.31	0.9195	37.72	0.9740
EDSR [23]	$\times 2$	38.11	0.9602	33.92	0.9195	32.32	0.9013	32.93	0.9351	39.10	0.9773
SRMDNF [43]	$\times 2$	37.79	0.9601	33.32	0.9159	32.05	0.8985	31.33	0.9204	38.07	0.9761
D-DBPN [10]	$\times 2$	38.09	0.9600	33.85	0.9190	32.27	0.9000	32.55	0.9324	38.89	0.9775
RDN [44]	$\times 2$	38.24	0.9614	34.01	0.9212	32.34	0.9017	32.89	0.9353	39.18	0.9780
RCAN (ours)	$\times 2$	38.27	0.9614	34.12	0.9216	32.41	0.9027	33.34	0.9384	39.44	0.9786
RCAN+ (ours)	$\times 2$	38.33	0.9617	34.23	0.9225	32.46	0.9031	33.54	0.9399	39.61	0.9788
Bicubic	$\times 3$	30.39	0.8682	27.55	0.7742	27.21	0.7385	24.46	0.7349	26.95	0.8556
SRCCNN [5]	$\times 3$	32.75	0.9090	29.30	0.8215	28.41	0.7863	26.24	0.7989	30.48	0.9117
FSRCCNN [6]	$\times 3$	33.18	0.9140	29.37	0.8240	28.53	0.7910	26.43	0.8080	31.10	0.9210
VDSR [16]	$\times 3$	33.67	0.9210	29.78	0.8320	28.83	0.7990	27.14	0.8290	32.01	0.9340
LapSRN [19]	$\times 3$	33.82	0.9227	29.87	0.8320	28.82	0.7980	27.07	0.8280	32.21	0.9350
MemNet [35]	$\times 3$	34.09	0.9248	30.00	0.8350	28.96	0.8001	27.56	0.8376	32.51	0.9369
EDSR [23]	$\times 3$	34.65	0.9280	30.52	0.8462	29.25	0.8093	28.80	0.8653	34.17	0.9476
SRMDNF [43]	$\times 3$	34.12	0.9254	30.04	0.8382	28.97	0.8025	27.57	0.8398	33.00	0.9403
RDN [44]	$\times 3$	34.71	0.9296	30.57	0.8468	29.26	0.8093	28.80	0.8653	34.13	0.9484
RCAN (ours)	$\times 3$	34.74	0.9299	30.65	0.8482	29.32	0.8111	29.09	0.8702	34.44	0.9499
RCAN+ (ours)	$\times 3$	34.85	0.9305	30.76	0.8494	29.39	0.8122	29.31	0.8736	34.76	0.9513

Bicubic	$\times 4$	28.42	0.8104	26.00	0.7027	25.96	0.6675	23.14	0.6577	24.89	0.7866
SRCCNN [5]	$\times 4$	30.48	0.8628	27.50	0.7513	26.90	0.7101	24.52	0.7221	27.58	0.8555
FSRCCNN [6]	$\times 4$	30.72	0.8660	27.61	0.7550	26.98	0.7150	24.62	0.7280	27.90	0.8610
VDSR [16]	$\times 4$	31.35	0.8830	28.02	0.7680	27.29	0.0726	25.18	0.7540	28.83	0.8870
LapSRN [19]	$\times 4$	31.54	0.8850	28.19	0.7720	27.32	0.7270	25.21	0.7560	29.09	0.8900
MemNet [35]	$\times 4$	31.74	0.8893	28.26	0.7723	27.40	0.7281	25.50	0.7630	29.42	0.8942
EDSR [23]	$\times 4$	32.46	0.8968	28.80	0.7876	27.71	0.7420	26.64	0.8033	31.02	0.9148
SRMDNF [43]	$\times 4$	31.96	0.8925	28.35	0.7787	27.49	0.7337	25.68	0.7731	30.09	0.9024
D-DBPN [10]	$\times 4$	32.47	0.8980	28.82	0.7860	27.72	0.7400	26.38	0.7946	30.91	0.9137
RDN [44]	$\times 4$	32.47	0.8990	28.81	0.7871	27.72	0.7419	26.61	0.8028	31.00	0.9151
RCAN (ours)	$\times 4$	32.63	0.9002	28.87	0.7889	27.77	0.7436	26.82	0.8087	31.22	0.9173
RCAN+ (ours)	$\times 4$	32.73	0.9013	28.98	0.7910	27.85	0.7455	27.10	0.8142	31.65	0.9208
Bicubic	$\times 8$	24.40	0.6580	23.10	0.5660	23.67	0.5480	20.74	0.5160	21.47	0.6500
SRCCNN [5]	$\times 8$	25.33	0.6900	23.76	0.5910	24.13	0.5660	21.29	0.5440	22.46	0.6950
FSRCCNN [6]	$\times 8$	20.13	0.5520	19.75	0.4820	24.21	0.5680	21.32	0.5380	22.39	0.6730
SCN [39]	$\times 8$	25.59	0.7071	24.02	0.6028	24.30	0.5698	21.52	0.5571	22.68	0.6963
VDSR [16]	$\times 8$	25.93	0.7240	24.26	0.6140	24.49	0.5830	21.70	0.5710	23.16	0.7250
LapSRN [19]	$\times 8$	26.15	0.7380	24.35	0.6200	24.54	0.5860	21.81	0.5810	23.39	0.7350
MemNet [35]	$\times 8$	26.16	0.7414	24.38	0.6199	24.58	0.5842	21.89	0.5825	23.56	0.7387
MSLapSRN [20]	$\times 8$	26.34	0.7558	24.57	0.6273	24.65	0.5895	22.06	0.5963	23.90	0.7564
EDSR [23]	$\times 8$	26.96	0.7762	24.91	0.6420	24.81	0.5985	22.51	0.6221	24.69	0.7841
D-DBPN [10]	$\times 8$	27.21	0.7840	25.13	0.6480	24.88	0.6010	22.73	0.6312	25.14	0.7987
RCAN (ours)	$\times 8$	27.31	0.7878	25.23	0.6511	24.98	0.6058	23.00	0.6452	25.24	0.8029
RCAN+ (ours)	$\times 8$	27.47	0.7913	25.40	0.6553	25.05	0.6077	23.22	0.6524	25.58	0.8092

Experiments

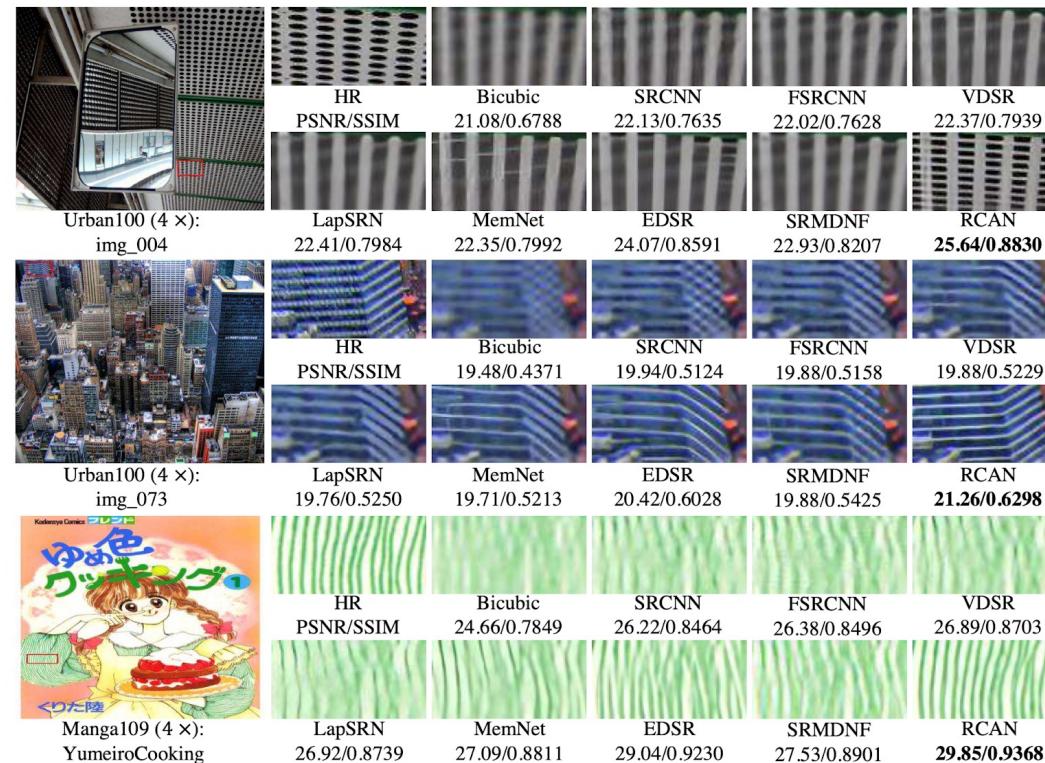


Fig. 5. Visual comparison for 4× SR with BI model on Urban100 and Manga109 datasets. The best results are highlighted

Experiments

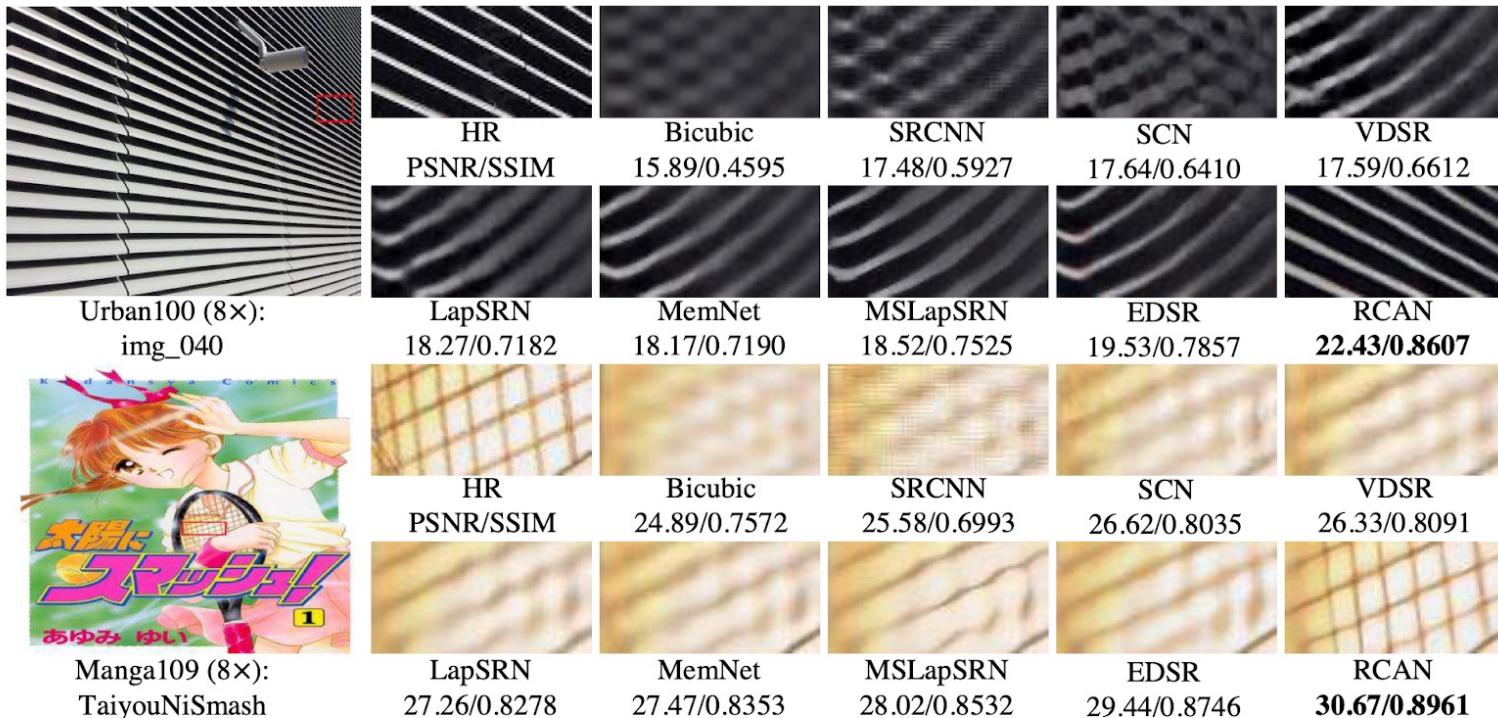


Fig. 6. Visual comparison for 8x SR with BI model on Urban100 and Manga109 datasets. The best results are **highlighted**

Experiments

Table 3. Quantitative results with BD degradation model. Best and second best results are **highlighted** and underlined

Method	Scale	Set5		Set14		B100		Urban100		Manga109	
		PSNR	SSIM								
Bicubic	×3	28.78	0.8308	26.38	0.7271	26.33	0.6918	23.52	0.6862	25.46	0.8149
SPMSR [29]	×3	32.21	0.9001	28.89	0.8105	28.13	0.7740	25.84	0.7856	29.64	0.9003
SRCNN [5]	×3	32.05	0.8944	28.80	0.8074	28.13	0.7736	25.70	0.7770	29.47	0.8924
FSRCNN [6]	×3	26.23	0.8124	24.44	0.7106	24.86	0.6832	22.04	0.6745	23.04	0.7927
VDSR [16]	×3	33.25	0.9150	29.46	0.8244	28.57	0.7893	26.61	0.8136	31.06	0.9234
IRCNN [42]	×3	33.38	0.9182	29.63	0.8281	28.65	0.7922	26.77	0.8154	31.15	0.9245
SRMDNF [43]	×3	34.01	0.9242	30.11	0.8364	28.98	0.8009	27.50	0.8370	32.97	0.9391
RDN [44]	×3	34.58	0.9280	30.53	0.8447	29.23	0.8079	28.46	0.8582	33.97	0.9465
RCAN (ours)	×3	<u>34.70</u>	<u>0.9288</u>	<u>30.63</u>	<u>0.8462</u>	<u>29.32</u>	<u>0.8093</u>	<u>28.81</u>	<u>0.8647</u>	<u>34.38</u>	<u>0.9483</u>
RCAN+ (ours)	×3	34.83	0.9296	30.76	0.8479	29.39	0.8106	29.04	0.8682	34.76	0.9502

Experiments

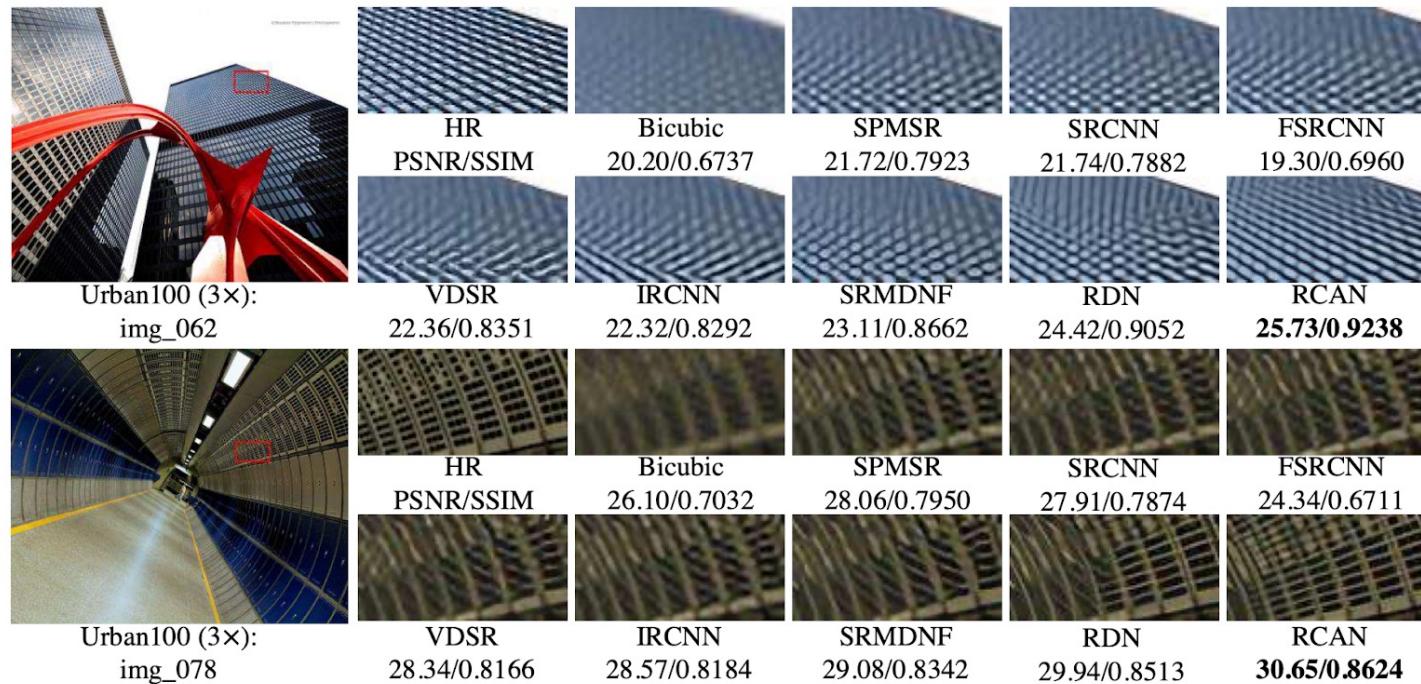


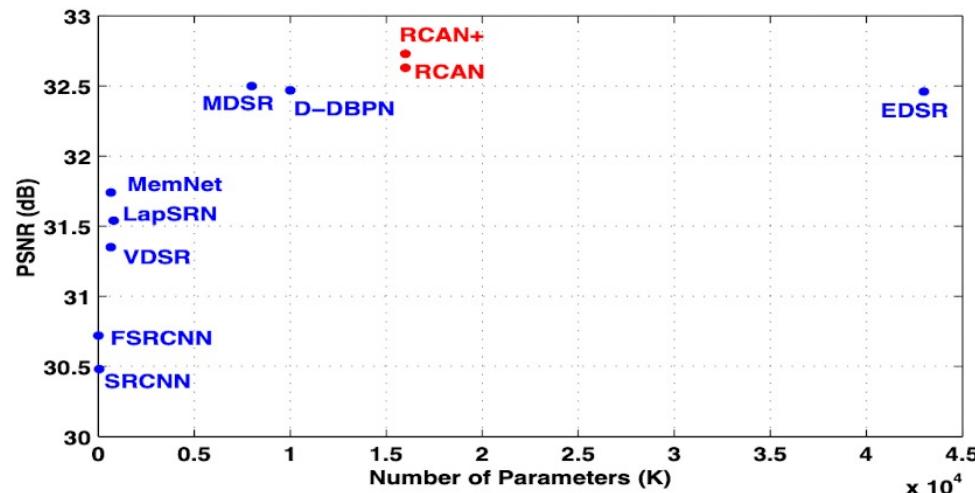
Fig. 7. Visual comparison for 3x SR with BD model on Urban100 dataset. The best results are **highlighted**

Experiments

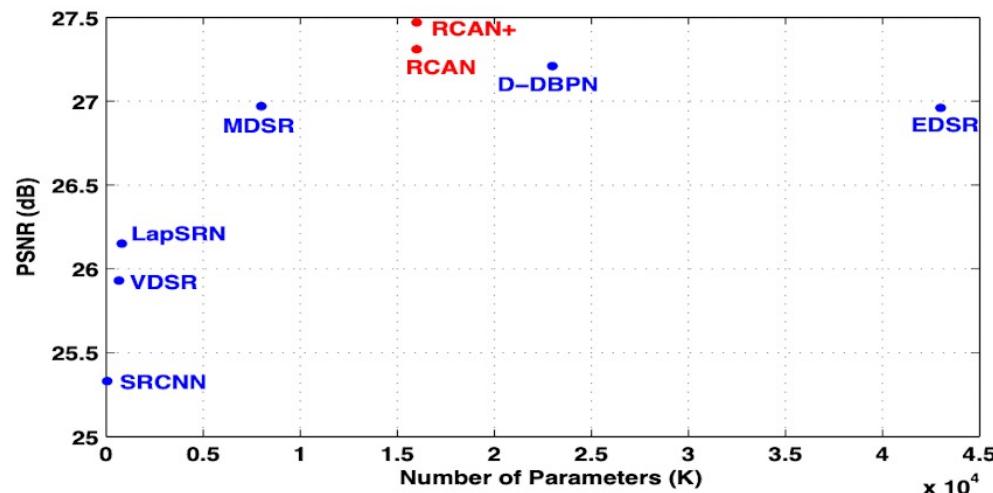
Table 4. ResNet object recognition performance. The best results are **highlighted**

Evaluation	Bicubic	DRCN [17]	FSRCNN [6]	PSyCo [30]	ENet-E [31]	RCAN	Baseline
Top-1 error	0.506	0.477	0.437	0.454	0.449	0.393	0.260
Top-5 error	0.266	0.242	0.196	0.224	0.214	0.167	0.072

Experiments



(a) Results on Set5 (4 \times)



(b) Results on Set5 (8 \times)

Fig. 8. Performance and number of parameters. Results are evaluated on Set5

QA